Assessments

Calaveras River Fish Migration Barriers Assessment Report

RESOURCE RESTORATION DIVISION OF PLANNING & LOCAL ASSISTANCE DEPARTMENT OF WATER RESOURCES

SEPTEMBER 2007

Front cover photos (clockwise from top):
Hosie Low Flow Crossing; Mormon Slough Tressel;
Caprini Low Flow Crossing; Calaveras Headworks

Fish Passage Improvement Program

Calaveras River Fish Migration Barriers Assessment Report

Assessments

September 2007

Arnold Schwarzenegger	**Mike Chrisman**	**Lester A. Snow**
Governor	Secretary for Resources	Director
State of California	The Resources Agency	Department of Water Resources

The format of the Calaveras River Fish Migration Barriers Assessment Report is new. It allows for digital presentation on the Internet, compact disk (CD), and computer screen. It also allows for economical printing of the document.

Foreword

In 2005, The California Department of Water Resources published the inaugural *Bulletin 250 – Fish Passage Improvement*. The bulletin was the result of a joint interagency collaboration between the Department, the Department of Fish and Game, NOAA's National Marine Fisheries Service, and the US Fish and Wildlife Service through CALFED's Ecosystem Restoration Program. The document recognized the depletion of migratory fish species caused by artificial structures in the Sacramento and San Joaquin River systems. Bulletin 250 promoted continued and increased actions by governments and private organizations for the protection and recovery of listed anadromous salmonid species in California.

This publication, *Calaveras Fish Migration Barriers Assessment Report*, is one of those actions. The Department in cooperation with Stockton East Water District and with assistance from the Department of Fish and Game, NOAA's National Marine Fisheries Service, and US Fish and Wildlife Service produced this document to be used for improving access into the lower Calaveras River for migrating seaward rainbow trout (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*).

This publication provides an inventory and evaluation of barriers on the Calaveras River system—its confluence with the San Joaquin River to New Hogan Dam, the Mormon Slough flood control channel, and the Stockton Diverting Canal. Numerous low flow road crossings, flashboard dams, and other structures exist in the Calaveras River and Mormon Slough that impede fish migration. The largest structure is Bellota Weir. The screening of the diversion and development of a permanent fish ladder at Bellota Weir are being addressed by Stockton East Water District. The results of this report will be used in conjunction with salmon and migratory rainbow trout life history data to identify and prioritize potential fish passage improvement projects to assist in the restoration of habitat and migratory pathways in the Calaveras River system.

The information that this report provides will promote the establishment of additional studies, programs, and projects, leading to cooperative efforts to improve listed and non-listed anadromous fish populations in the Calaveras River and Bay-Delta ecosystem.

Mark W. Cowin
Deputy Director
Regional Water Planning and Management

State of California
Arnold Schwarzenegger, Governor

The Resources Agency
Mike Chrisman, Secretary for Resources

Department of Water Resources
Lester A. Snow, Director

Kasey Schimke
Assist. Director Legislative Affairs

David Sandino
Chief Counsel

Susan Sims-Teixeira
Assist. Director Public Affairs

Timothy Haines
Deputy Director

Leslie Harder Jr.
Deputy Director

Reuben Jimenez
Deputy Director

Gerald E. Johns
Deputy Director

Mark W. Cowin
Deputy Director

Ralph Torres
Deputy Director

Division of Planning and Local Assistance

Resource Restoration and Project Support Branch
Mark Meeks, Chief

Resource Restoration Section
Ted Frink, Environmental Program Manager

Project Support Section
Matt Nolberg, Supervising Engineer

Prepared under the supervision of

Leslie Pierce, Fish Passage Improvement Program ....Senior Environmental Scientist
Debbie Carlisle, Engineering Support .... Senior Engineer

Prepared by

Marjorie Caisley....................................Engineer
Varda Disho ....Engineer
Kevin Faulkenberry....................Senior Engineer
Michael Hendrick........... Environmental Scientist
Tracy Middleton .... Engineer
Bonnie Ross ....Environmental Scientist
Megan Sheely................Environmental Scientist
Byron Willems..................................... Engineer

Editorial and design services provided by Division Publications

Gretchen Goettl .... Supervisor of Technical Publications

Mike Durant.............................. Research Writer
James Joelson .... Research Writer
Carole Rains.............................Research Writer
Marilee Talley ....Research Writer

Acknowledgments

Many individuals and organizations contributed significant time, expertise, and energy to the Calaveras River Fish Migration Barriers Assessment Report. Collection and review of existing reports and databases, aerial photographs, topographic maps, website links, and personal interviews and conversations were conducted. The Fish Passage Improvement Program is grateful to many including:

Calaveras County Water District
James Cornelius

Department of Water Resources
DPLA Headquarters– Margie Caisley, Debbie Carlisle, Dave Ching, Allan Davis, Varda Disho, Mike Durant, Ted Frink, Gretchen Goettl, Mike Hendrick, James Joelson, Derick Louie, Tracy Middleton, Leslie Pierce, Carole Rains, Bonnie Ross, and Marilee Talley

San Joaquin District– Kevin Faulkenberry, Robert Lampa, Paul Romero, and Byron Willems

Department of Fish and Game
Ian Drury, George Edwards, George Heise, and Katie Perry

Fishery Foundation
Trevor Kennedy

NOAA’s National Marine Fisheries Service
Jeff McLain, Erin Strange, and Steve Thomas

SP Cramer & Associates
Jim Inman, Andrea Fuller, and Michele Simpson

Stockton East Water District
Kevin Kauffman, Andres Lozano, Jeanette Thomas, and John Yoshimura

US Army Corps of Engineers
Phil Holcomb

US Fish and Wildlife Service
J.D. Wikert

Executive Summary

Artificial structures play a major role in reducing Calaveras River's productivity as a migrating seaward rainbow trout (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*) fishery. The river is in the range of historical and essential fish habitat for fall-run Chinook salmon and part of the historical distribution of Central Valley rainbow trout. In cooperation with Stockton East Water District, the Department of Water Resources' Fish Passage Improvement Program studied and assessed the physical and hydraulic conditions of 97 artificial structures in the Calaveras River from New Hogan Dam downstream to the confluence with the San Joaquin River.

These structures are low-flow road crossings with culverts, low-flow road crossings without culverts, bridges, permanent dams and weirs, and flashboard dams with the flashboards removed. Each structure was evaluated for fish passage and scored on its potential as a barrier to fish passage. Possible scores ranged from 0 to 7, with 7 designating the greatest potential to impair fish passage. Clements Road Flashboard Dam on the Calaveras River was the only structure to score 7. Forty-nine structures received a score of 0; all of them are bridges that have no apron or riprap. A ranking of 0 does not guarantee passage; it only indicates the structure has similar passage performance to normal channel cross sections.

The seasonal flashboard dams were also evaluated with their flashboards installed. A revised scoring system was developed to incorporate the unique characteristics of these structures. The possible scores ranged from 0 to 9, with 9 designating the greatest potential to impair fish passage. Cherryland, Panella, Lavaggi, McLean, Prato, and Clements dams all received 9 points. Murphy Flashboard Dam had the lowest score of 3 points.

Seventeen structures were selected to be modeled using HEC-RAS, the US Army Corps of Engineers one-dimensional open channel flow model. These structures were selected because they are representative of the different structure types and are the most severe in regard to impaired fish passage. The model allowed the calculation of the percentage of time that adult and juvenile fish can pass through a structure during their migration period. Clements Road Flashboard Dam was the most severe, allowing *O. tshawytscha* and *O. mykiss* passage only 2% and 5% of their migration periods, respectively. Additionally, juveniles only have passage during 15% of their migration period. None of the 17 structures allowed 100% passage during the adult Chinook, *O. mykiss*, or juvenile migration periods. This implies that all 97 structures on Calaveras River, Mormon Slough, and Stockton Diverting Canal represented by the modeled structures are likely to be impassable at some point during each migration season. Riprap was often the feature that had the greatest impact on fish passage at modeled structures, indicating that the use of riprap should be eliminated at structures and in the channel where possible.

To increase the Calaveras River's productivity as an *O. tshawytscha* and *O. mykiss* fishery, many structures on the Calaveras River system must be retrofitted to allow passage for adult and juvenile salmonids. Both temporary and permanent modifications are needed to prevent further decline in fish populations. This report provides a basis for various temporary and permanent structure solutions to the impaired fish passage these structures create. Such solutions are being developed on a preliminary or conceptual level for eight of the structures identified in this report.

Table of Contents

Acronyms and Abbreviations

af	acre-feet
cfs	cubic feet per second
DFG	California Department of Fish and Game
DO	dissolved oxygen
DWR	California Department of Water Resources
ESU	Evolutionarily Significant Unit
FFC	Fishery Foundation of California
FPIP	Fish Passage Improvement Program
fps	feet per second
HEC-RAS	Hydrologic Engineering Centers River Analysis System
NMFS	National Marine Fisheries Service
SEWD	Stockton East Water District
USACE	US Army Corps of Engineers
USBR	US Bureau of Reclamation
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey

Metric Conversion Table

Quantity	*To Convert from Metric Unit*	*To Customary Unit*	*Multiply Metric Unit By*	*To Convert to Metric Unit Multiply Customary Unit By*
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

Chapter 1 Introduction

Contents

Blank page for 2-sided printing

Chapter 1 Introduction

All Chinook salmon runs in California have declined, some to extinction. The biggest cause of the decline in populations has been the dams and diversions on the major rivers, according to Peter B. Moyle in his *Inland Fishes of California* (2002). Moyle, a University of California, Davis, professor of fish biology, says the Sacramento-San Joaquin River system dams have denied salmon access to more than 50% of the stream reaches salmon formerly used and to 80% of their historical holding and spawning habitat.

The Calaveras River (Figure 1-1) is in the range of historical and essential fish habitat for fall-run Chinook salmon, and part of the historical distribution of Central Valley steelhead trout. The Calaveras River is part of CALFED's East Side Delta Tributaries Ecological Management Zone. Improving anadromous fish passage on the Calaveras River will help meet goals and milestones designated by CALFED.

Field observations and evaluations by California Department of Water Resources (DWR), the Fishery Foundation of California, US Fish and Wildlife Service, and California Department of Fish and Game (DFG) have found that instream structures on the Calaveras River downstream of the Calaveras Headworks, on the Stockton Diverting Canal, and on Mormon Slough limit access to upstream spawning areas, particularly under low-flow conditions.

Reports and Study

One goal of DWR's Fish Passage Improvement Program is to collect data on artificial structures in waterways that impede migration and spawning of anadromous fish. With the data, we can then identify and evaluate the potential to modify or remove those structures. In cooperation with Stockton East Water District (SEWD), we studied and assessed the physical and hydraulic conditions of artificial structures in the Calaveras River from New Hogan Dam downstream to the confluence with the San Joaquin River, in the Stockton Diverting Canal, and in Mormon Slough. We determined which structures may be barriers to migrating *Oncorhynchus mykiss* (see sidebar) and *O. tshawytscha* (Chinook salmon).

Our study produced an inventory of instream structures, a scoring of these structures in regards to their potential impairment of fish passage, and hydraulic modeling for a representative 17 of these structures. Our data and analysis are presented in the first two parts of "Calaveras River Fish Migration Barriers Assessment Report": "Assessments" and "Appendices." The third part of this report, "Selected Preliminary Designs," can be used by various groups or agencies to implement fish passage improvement projects on the Calaveras River.

Assessments and Appendices

In "Calaveras River Fish Migration Barriers Assessment Report -- Assessments", we describe the hydrology and water supply operation of the Calaveras River basin and existing biological conditions. We also explain our evaluation methods, which relied on the capacity of the river, fish passage criteria developed by DFG and the National Marine Fisheries Service

Figure 1-1 Calaveras River watershed

DWR = California Department of Water Resources

DFG = California Department of Fish and Game

SEWD = Stockton East Water District

Anadromous fish are those that are hatched in fresh water, travel to the ocean as juveniles where they remain for most of their adult lives, and return to fresh water to spawn.

Oncorhynchus mykiss is used throughout this report because various agencies are not in agreement regarding which form of trout (the resident rainbow, or anadromous steelhead) are present in the segment of the Calaveras River discussed in this report.

The focus of this report is on assessing fish passage, and we are leaving it to other agencies to determine the form of *O. mykiss* present in the river.

(NMFS), and engineering standards for instream structures. A glossary and bibliography of cited references appear in Chapter 7 and 8, respectively. In the second part, “Appendices,” we detail site descriptions (Appendix A), provide examples of data sheets used for scoring structures (Appendix B) and flow duration analyses (Appendix C) and hydraulic modeling based on original raw data (Appendix D). Appendix E is a table of structures with location information, including longitudes and latitudes.

NMFS = National Marine Fisheries Service

Hydrology and Water Supply Operation

Within the Calaveras River watershed, anadromous fish have access to 38 miles of the river between New Hogan Dam and the San Joaquin River via Mormon Slough and 36 miles via the Calaveras River. The river was first impounded by the city of Stockton in 1930 for flood control. New Hogan Dam was built in 1964 and substantially altered flows in the river. Water from the New Hogan Project is used for irrigation and municipal purposes with the water right permit held by the US Bureau of Reclamation. In 1970, SEWD and the Calaveras County Water District contracted with USBR for the project’s entire water supply. In 1978, SEWD began to divert water at Bellota Weir, further altering water flow patterns in the river system.

USBR = US Bureau of Reclamation

In Chapter 2, we present historical streamflow data from the US Army Corps of Engineers and flow patterns documented by the DFG and Fishery Foundation. Observations and surveys by individuals with these agencies and contractors expanded our description of hydrology and water supply operations on the Calaveras River.

Maps and tables (Chapter 2) identify 100 artificial structures downstream of New Hogan Dam on the Calaveras River, Stockton Diverting Canal, and Mormon Slough. Ninety-seven of these structures were studied and assessed. The Calaveras River system has six main types of structures:

Lists of structures on:

Calaveras River (Table 2-2)

Stockton Diverting Canal (Table 2-3)

Mormon Slough (Table 2-4)

- Flashboard dam bases (boards removed)[1]
- Seasonal flashboard dams (boards in place)[1]
- Low-flow road crossing without culverts
- Permanent dams and weirs
- Road and low-flow road crossings with culverts
- Vehicle, pedestrian, and railroad bridges

Biological Conditions

Before evaluating the structures and proposing improvements, we cataloged the river’s fish populations, migration patterns, and habitat conditions. We relied on our own observations and recent published surveys. We collated the information in Chapter 3 Biological Conditions, where tables list migration periods and fish survey results.

Fish Passage Evaluation Methodology and Results

Fish passage is considered to be impaired when fish passage criteria are not met throughout the defined range of fish passage flows. We reviewed the most recent DFG and NMFS publications to develop criteria for fish passage evaluations for structures on the Calaveras River system. In Chapter 4, we

[1] Each flashboard dams was treated as two separate types of structures due to its intermittent use for seasonal irrigation diversions.

detail criteria for juvenile and adult anadromous salmonids for upstream and downstream migration.

We evaluated fish passage in two phases. In the first phase, we visited structure sites, took notes on their biological and morphological conditions, and measured the dimensions of the physical features of the structures that affect fish passage. Based on these measurements, we scored 97 structures regarding their potential impediment to fish passage (see Chapter 5, Table 5-1). Twenty-two of the scored structures were flashboard dams or had flashboard components. Nineteen were scored and evaluated with their flashboards removed. This scoring helps prioritize fish passage improvement projects in the river system.

Table 5-1 Structure scoring

Possible scores ranged from 0 to 7 with 7 indicating the greatest potential to impair fish passage. The only structure to obtain a score of 7 was Clements Road Flashboard Dam on the Calaveras River. There were 49 structures with a score of 0; all of these were bridges with no apron or riprap. A scoring of 0 does not guarantee passage; it only indicates the structure has similar passage performance to normal channel cross sections.

Nineteen of the 22 seasonal flashboard dams or related structures were also scored again separately, but with their flashboards installed. A separate 9-point scoring system was developed for these cases (see Chapter 5, Table 5-2). Cherryland, Panella, Lavaggi, McClean, Prato, and Clements dams received the highest points. They had drops of more than 3 feet with plunge pools less than 2 feet deep and exposed riprap downstream of the drop. Three seasonal flashboards were not scored because the boards were not installed at the time of our visit.

Table 5-2 Scoring of flashboard dams with boards in place

In the second phase of fish passage evaluations, we used hydraulic modeling to assess fish passage under a range of flows dictated by DFG guidelines. Knowing fish passage capabilities for a range of flows at a structure is necessary to identify the type of barrier the structure presents. We prepared models and analyzed the results for 17 structures downstream of Bellota Weir and Calaveras Headworks to determine the percent of time fish can pass unimpaired and to categorize the structures as partial, temporal, or total barriers. Clements Road Flashboard Dam and Bridge scored the worst, allowing for adult Chinook salmon and *O. mykiss* passage only 2% and 5% of their migration periods, respectively. Juveniles only have unimpaired passage 15% of their migration period.

Preparing models and analyzing their results is necessary before designing fish passage improvements at a structure. Models are described in Chapter 5; details of early HEC-RAS models are in Appendix D.

HEC-RAS is hydraulic modeling software developed by the US Army Corps of Engineers Hydraulic Engineering Center. The software allows rapid one-dimensional steady and unsteady flow calculations.

Assessment Findings

None of the 17 structures modeled allowed 100% passage during the adult Chinook, *O. mykiss*, or juvenile migration periods. This implies that all 97 structures on Calaveras River, Mormon Slough, and Stockton Diverting Canal represented by the modeled structures are likely to be impassable at some point during each migration season.

Riprap was often the feature that had the greatest impact on fish passage at modeled structures. Riprap was responsible for passage problems at 10 of the 17 modeled structures, indicating that the use of riprap should be eliminated at structures and in the channel where possible. The remaining structures were limited by high velocities over the structure (two sites), shallow depth over the structures (three sites), and shallow depths in the channel (two sites). Bridges on the Calaveras River, Mormon Slough, and Stockton Diverting Canal also may have some percentage of impairment.

Many artificial structures on the Calaveras River system need retrofits to allow passage for adult and juvenile salmonids. Both adult and juvenile salmonids find similar passage problems with strong currents (velocities), depth, and distance of drop over the structure. Channel velocity and depth are important for adults during their upstream migration. Pool depths and jump heights also are important.

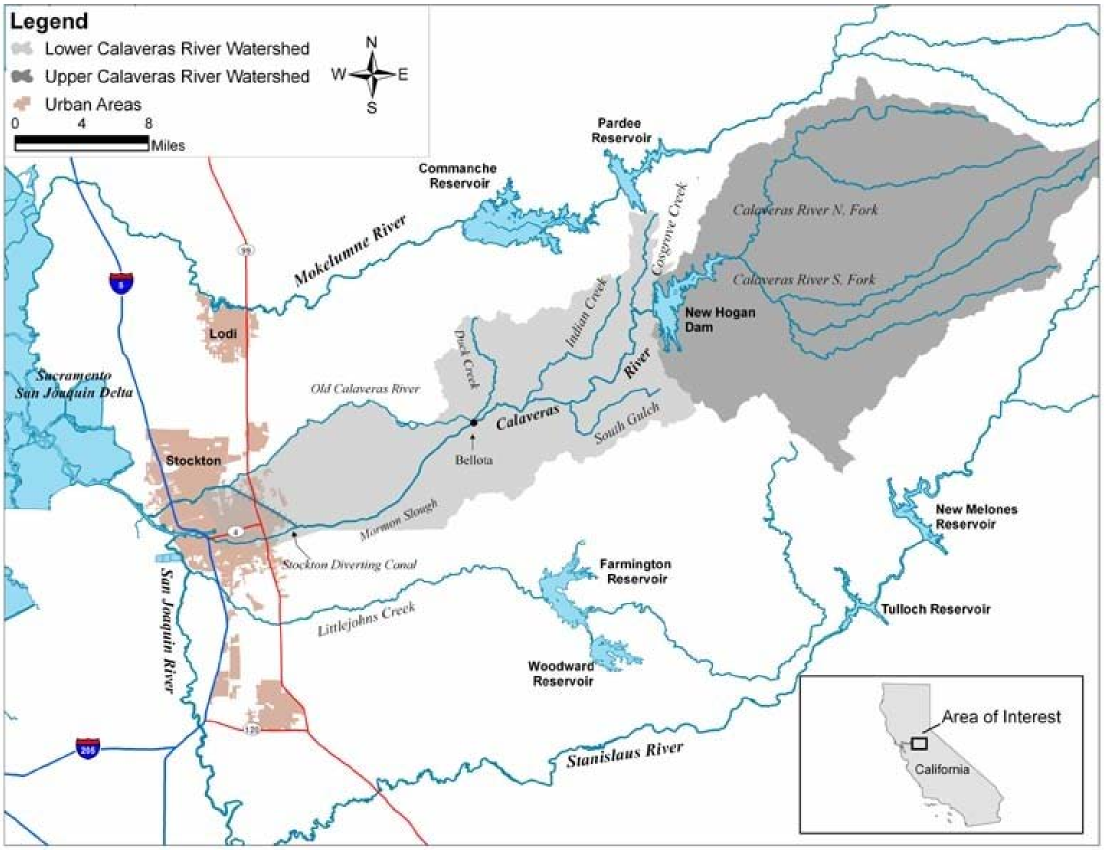
Selected Preliminary Designs

The third part of this report, “Calaveras River Fish Migration Barriers Assessment Report – Selected Preliminary Designs” presents six preliminary designs for fish passage solutions for modeled structures: Cherryland and Clements flashboard dams and Gotelli Low-flow Road Crossing on the Calaveras River, Budiselich Flashboard Dam on Stockton Diverting Canal, and Caprini and Hosie low-flow road crossings on Mormon Slough. In addition, conceptual designs are presented for Calaveras Headworks on the Calaveras River and Central California Traction Railroad Crossing on Stockton Diverting Canal.

Each of the eight design sections are interdependent with an introductory “essentials” section, titled “Design of Fish Passage Solutions.” The section contains, among other things, a basis of design, general temporary and permanent solutions, and final design recommendations. The basis of design contains NMFS and DFG fish passage criteria as well as descriptions of general design methods supported by engineering formulas. These general design methods, which include pool and weirs, ladders and step pool grade control structures, have proven over time to suit certain site and flow conditions. To illustrate these concepts, a photo gallery of various types of completed fish passage projects is included. For most structures, respective to DFG minimum-flow guidelines, these fish passage design solutions in general direct low flows into paths for migrating salmonids.

Also included is a section on fish passage solutions that are generic in nature. They are divided into two categories: temporary retrofits and more-permanent solutions. Respective to DFG minimum-flow guidelines, these fish passage solutions, at most structures, would direct low flows into paths for migrating salmonids.

Figure 1-1. Calaveras River watershed



Source: S.P. Cramer and Associates

Chapter 2 Existing Hydrologic and Water Supply Operations

Contents

Blank page for 2-sided printing

Chapter 2 Existing Hydrologic and Water Supply Operations

The Calaveras River watershed covers 470 square miles with its headwaters at 4,365 feet elevation (Figure 2-1). The south and north forks of the Calaveras River combine to form New Hogan Lake behind New Hogan Dam at 700 feet elevation. Downstream of New Hogan Dam at river mile 26 the river splits into two channels, the Calaveras River and Mormon Slough.

Figure 2-1. Calaveras River watershed

cfs = cubic feet per second

SEWD = Stockton East Water District

New Hogan Dam controls flows in the river downstream of New Hogan Lake. The dam is a complete fish migration barrier. Nineteen miles downstream of New Hogan Dam is a 65-cubic-feet-per-second (cfs) municipal and agricultural diversion at Bellota Weir. The weir diverts water into the Stockton East Water District's (SEWD) municipal water treatment plant. When appropriate water flows exist, 38 miles of the river between New Hogan Dam and the San Joaquin River via Mormon Slough are accessible to *Oncorhynchus mykiss* and *O. tshawytscha* (Chinook salmon) (Figure 2-2). Table 2-1 lists distances for each channel segment.

Figure 2-2. Lower Calaveras River basin

Table 2-1. Distances for segments of the Calaveras River and associated channels

Oncorhynchus mykiss is used throughout this report because various agencies are not in agreement regarding which form of trout (the resident rainbow, or anadromous steelhead) are present in the segment of the Calaveras River discussed in this report.

The focus of this report is on assessing fish passage, and we are leaving it to other agencies to determine the form of *O. mykiss* present in the river.

Instream structures

Artificial structures can become impediments to migratory salmonids depending on flow conditions from natural events, such as rain, or from human intervention, such as agricultural and municipal water delivery. Fish that enter the Stockton Diverting Canal and Mormon Slough can become stranded in pools downstream of structures when flows recede. These fish can die, become easy prey, or be poached before another storm allows fish to swim farther up the channel.

We identified 100 artificial structures downstream of New Hogan Dam on the Calaveras River, Stockton Diverting Canal, and Mormon Slough. The structures are identified in Tables 2-2, 2-3, 2-4. The Calaveras River system has six main types of structures:

- Flashboard dam bases (boards removed)
- Low-flow road crossing without culverts
- Permanent dams and weirs
- Road and low-flow road crossings with culverts
- Seasonal flashboard dams (boards in place)
- Vehicle, pedestrian, and railroad bridges

Table 2-2. Structures on the Calaveras River

Table 2-3. Structures on the Stockton Diverting Canal

Table 2-4. Structures on the Mormon Slough

Maps show the location of each structure. Identification numbers in the tables correspond to the numbers next to structure names on the maps. Figure 2-3a is a vicinity map showing the breakdown of maps that contain the structure locations. There are nine structure location maps (Figures 2-3b through 2-3j).

Figure 2-3a. Structure location—vicinity map

Figure 2-3b. Structure location–detail map 1

Figure 2-3c. Structure location–detail map 2

Figure 2-3d. Structure location–detail map 3

Figure 2-3e. Structure location–detail map 4

Figure 2-3f. Structure location–detail map 5

Figure 2-3g. Structure location–detail map 6

Figure 2-3h. Structure location–detail map 7

Figure 2-3i. Structure location–detail map 8

Figure 2-3j. Structure location–detail map 9

Basin Hydrology

The primary water source for the Calaveras River is seasonal rainfall because the watershed is at elevations lower than typical snow level. Normal annual precipitation for the watershed upstream of New Hogan Dam is 33.3 inches and ranges from about 24 inches at New Hogan Dam to nearly 50 inches in the basin upstream of New Hogan Lake. Normal annual precipitation for the watershed downstream of New Hogan Lake ranges from 14.2 inches in Stockton, 17.5 inches at Bellota, and 18.9 inches at Jenny Lind.

The river was first impounded by the city of Stockton in 1930 for flood control. New Hogan Dam, built in 1964, holds just over two times the mean annual runoff of the watershed. Because of the larger capacity of New Hogan Lake relative to the average annual inflow, spills occur only in wet years. New Hogan Lake substantially altered the timing, magnitude, and duration of flows in the river (USFWS 1998). The former seasonal hydrology of the lower elevation river was replaced with a steady flow of water year round in the river between New Hogan Dam and Bellota Weir. In 1978, SEWD began operation of a diversion of 65 cfs at Bellota resulting in an altered water flow pattern upstream and downstream of the diversion (USFWS 1993). Outside of the April to October irrigation season, Mormon Slough and the Calaveras River downstream of the Headworks may have little to no flow due to reduced releases from the reservoir and diversion into the SEWD municipal diversion at Bellota.

[USFWS] US Fish and Wildlife Service. 1998. Central Valley Project Improvement Act Tributary Production Enhancement Report. Central Valley Fish and Wildlife Restoration Program Office. Sacramento. May

[USFWS] US Fish and Wildlife Service. 1993. Memorandum. From Wayne S. White, Field Supervisor, Sacramento Field Office, Sacramento, California to David Lewis, Regional Director, Bureau of Reclamation, Sacramento. Jan 28

Streamflow on the Calaveras River has been gaged at several locations since 1907. The longest record is from the US Geological Survey (USGS) gage at Jenny Lind from 1907 to 1966. After completion of New Hogan Dam, the gage was discontinued, and a new one was established at New Hogan Dam Road bridge (see Figure 2-3g) less than a mile downstream of the dam. The USGS operated this gage from 1961 to 1992. There is also a gage at New Hogan Dam, operated by the US Army Corps of Engineers (USACE) that has recorded flows from 1964 to present time. The California Department of Water Resources in the past also operated gages on the Calaveras River system. The DWR gage on Mormon Slough at Bellota Weir is now operated by USACE. The USACE also maintains a gage on Cosgrove Creek, a tributary to the Calaveras River, which was previously used by the USGS. Table 2-5 lists gages and their period of record in the Calaveras River. Figure 2-4 depicts the gage locations.

USGS = US Geological Survey

USACE = US Army Corps of Engineers

Table 2-5. Gages on the Calaveras River

Figure 2-4. Stream gage locations

Salmonid migration in the Calaveras River system is triggered by rainfall events or flood control releases from New Hogan Dam that provide sudden increases in flow in the river system. Migrations can be triggered by flows less than 100 cfs (DFG 1993). Because of the storage available at New Hogan Dam, most rainfall-runoff hydrographs tend to be short, lasting only a day or two. Historically, runoff from the upper watershed would likely sustain flow for longer periods because of the travel time for the runoff to reach the lower watershed. Today, the upper watershed runoff is captured in New Hogan Lake and released for drinking and irrigation water during the

[DFG] California Department of Fish and Game. 1993. Restoring Central Valley Stream: a plan for action. Inland Fisheries Division. Compiled by F.L. Reynolds, T.J. Mills, R. Benthin, and A. Low. Report for public distribution, Nov 10, 1993. Inland Fisheries Division, Sacramento.

dry summer months. Thus, the tributaries downstream of New Hogan Dam are the major contributors of flow to the river during storm events. These tributaries contribute flow soon after the storm begins and stop flowing shortly after the storm ends. Because of the short duration of storm runoff, there is a rapid transition from continuous flow in the river to disconnected pools of water. This rapid transition traps fish that have started their migration. They will be unable to spawn unless another storm occurs quickly. A storm event was observed in December 2001 that illustrates this typical runoff pattern in the Calaveras River.

Downstream of Bellota Weir in Mormon Slough and the Stockton Diverting Canal, biologists at the Fishery Foundation of California noted patterns of flow connectivity during peak runoff events followed by decreasing flows and drying channels with disconnected pools remaining. During one observation period, increased runoff occurred from December 3 to December 6, 2001 (Figure 2-5). Once runoff ceased, surveyors visited the bridges at Escalon-Bellota, Fine, Flood, Milton, and Duncan Roads (see Figures 2-3e, 2-3f, 2-3i, and 2-3j) along Mormon Slough. On December 3, flow remained substantial (no dry areas seen upstream or downstream of crossings) down to Milton Road, where dry, impassible stretches were present upstream and downstream of the bridge. On December 4, flow was observed as far downstream on Main Street Bridge over the Stockton Diverting Canal. On December 5 and 6, slow moving, shallow water was observed at Escalon-Bellota Road, and standing water was found under the other road bridges downstream. There were dry stretches upstream and downstream of Milton Road. Average flows recorded at the Mormon Slough gage were 21 cfs on December 3, 13 cfs on December 4, 5 cfs on December 5, and 1 cfs on December 6 (Collins 2002 pers comm).

Figure 2-5. Hydrograph of Mormon Slough at Bellota Weir, 2-6 Dec 2001

Personal communication: Collins, Dillon. S.P. Cramer and Associates. December 2002. Dillon.Collins@valleyair.org.

In 1955, 1972, 1976, and 2001 observations of salmonids attempting to migrate up the Stockton Diverting Canal and Mormon Slough showed that flows less than 100 cfs have been enough to attract salmon into the channel (DFG 1993). For example, in March 1955 salmonids were observed stranded in a pool downstream of the railroad trestle and outlet of Potter Creek in Mormon Slough. Peak flow was 36 cfs that month at the Stockton Diverting Canal gage. In March 1972, salmon were found stranded in the Stockton Diverting Canal. The peak flow was 295 cfs that month at the New Hogan Dam gage and 50 cfs at the Stockton Diverting Canal gage. In April 1976, salmon were again stranded in the diverting canal. Peak flow was 276 cfs that month at New Hogan Dam. No flow data are available for that year downstream of Bellota Weir. In November 2001, fish were stranded in the Stockton Diverting Canal at Budiselich Dam (see Figure 2-3h). Peak flow was 23 cfs that month at the Mormon Slough gage.

New Hogan Dam and Flood Control Operations

New Hogan Dam was constructed by the USACE during the period from 1960 to 1963. The dam was built to provide flood control, municipal and industrial water supply, irrigation, and recreational usage (USACE 1983). Operation of the reservoir is controlled by the USACE 1983 Water Control Manual. The maximum water storage capacity of the reservoir is 317,100 acre-feet (af). Storage at minimum pool is 15,000 af. The Water Control Manual designates the required reserved flood control volume and the allowable water storage volume. Table 2-6 is a brief summary of allowed water storage (SEWD 2001).

[USACE] US Army Corps of Engineers. 1983. New Hogan Dam and Lake, Calaveras River, California. Water Control Manual. Appendix III to Master Water Control Manual San Joaquin River basin, California. Sacramento District.

af = acre-feet

Table 2-6. New Hogan Dam allowed water storage

[SEWD] Stockton East Water District. 2001. Fall/Winter Calaveras River and Mormon Slough Operational Plan. Stockton, CA. December.

As noted, between January 1 and June 8 of each year, the allowable storage varies depending on the amount of seasonal rainfall received to date that year. If storage is not drawn down to the allowable 152,000 af by December 1 in each year, flood control releases are made to reach that level. To accommodate rainfall amounts greater than 12 inches in any one period, maximum allowable storage is limited to 152,000 af until March 20. Flood control releases are made to maintain the reservoir storage at 152,000 af.

Permit Restraints

The water right permit for the New Hogan Project is held by the US Bureau of Reclamation and allows diversion from May 1 through November 1 of each year; 200 cfs direct diversion and 325,000 af diversion to storage. The following condition was included in the water right permit held by USBR:

USBR = US Bureau of Reclamation

<u>Condition 8</u>

Diversions shall be made under this permit only during such times as surface flow exists in the stream channel between New Hogan Dam and a point on the Calaveras River Channel below its confluence with the Stockton Diversion Canal within projected Section 26, T2N, R6E, MDB&M.

This condition is in place as a protective measure for riparian users downstream of New Hogan Dam.

Stockton East Water District

SEWD obtains water for municipal and agricultural use from New Hogan Lake. Each year, the district takes into consideration the amount of stored water in the reservoir and the anticipated demand for water and makes a decision by mid-April regarding how much water it will be able to deliver.

In addition, SEWD buys water from New Melones Reservoir under an agreement with the Tri-Dam Project, a partnership between the Oakdale Irrigation District and the South San Joaquin Irrigation District. SEWD purchases up to 30,000 af from October through September based on availability of water supply.

SEWD also has a contract for 75,000 af from January 1 through December 31 with the Central Valley Project. Water from New Melones Reservoir is used for irrigation, groundwater recharge, and drinking water.

In practice, SEWD takes this water from May through September or November when water quality in the Calaveras River is low. New Melones water is transferred directly into the pipeline going into the SEWD water treatment plant. In winter, when water quality in the Calaveras River is better, the district diverts water from New Hogan into its municipal diversion at Bellota Weir.

In 1970, SEWD and the Calaveras County Water District contracted with USBR for the entire water supply from the New Hogan Project. The contract states that the federal government must store, regulate, and release all flows of the Calaveras River at New Hogan for the purpose of making available agricultural, municipal, industrial, and domestic water for use by the districts. This storage, regulation, and release of water is subordinate only to storage and release of water for flood control, to maintain a storage pool of 15,000 af, and to release unregulated runoff in the Calaveras River in recognition of prior downstream water rights.

SEWD Water Supply Allocation

Water released from New Hogan Dam is used for municipal and irrigation purposes. During the non-irrigation season, November to March, released flow is diverted into the SEWD municipal diversion. Tables 2-7 and 2-8 show average diversion rates for normal (wet) and dry year operations, respectively.

Table 2-7.Releases from New Hogan for diversion at Bellota Weir: Normal (wet) year operations

Table 2-8. Releases from New Hogan for diversion at Bellota Weir: Dry year operations

Flow is not released downstream of Bellota in Mormon Slough or downstream of the Headworks in the Calaveras channel except when flood releases are made from New Hogan Dam or when storm runoff flows into the river and channels. Thus, stretches of Mormon Slough and the Stockton Diverting Canal remain dry for days, weeks, or months at a time during winter and early spring. The Calaveras channel downstream of the Headworks receives only storm runoff between November and March. During the April to October irrigation season, both channels (Mormon Slough and the Calaveras River) are watered to supply surface water to irrigators.

SEWD Irrigation Diversions

Depending on water use demand, the target start and end dates for each year's irrigation season are April 15 and October 15, respectively. Generally, if air temperatures are consistently high (approximately 80 ^{o}F or above) and precipitation totals low in the weeks prior to mid-April, water users may begin to make requests for water delivery. SEWD then installs flashboard dams where needed, and flows from New Hogan are increased in order to meet the demand. The start date can also be moved back if enough precipitation to curb the irrigation demand is received, although delays longer than one week are untypical (Collins 2002 pers comm). SEWD’s facilities include a series of small flashboard dams on the Calaveras River, Mormon Slough, Mosher Creek, and Potter Creek that facilitate the diversion of irrigation water.

SEWD will normally call for 75 to 100 cfs to be released from New Hogan at the initiation of the irrigation season. This amount of flow is needed to fill the channels to the levels required for irrigation pump operation (Collins 2002 pers comm). According to the superintendent of SEWD, water is typically allowed to flow down the Calaveras River channel until it reaches

Pezzi Dam or Solari Ranch Road (see Figure 2-3c). Once this happens, flow release from New Hogan Dam is often reduced to between 25 and 50 cfs, following the initial filling of the channels and before water reaches McAllen Road (see Figure 2-3c). The average peak release from New Hogan during high demand periods is estimated at 225 cfs. The mean New Hogan outflows during the 2000 and 2001 irrigation seasons were 162 and 185 cfs, respectively.

When water supply is adequate, water is diverted into Mormon Slough, Mosher Creek, Potter Creek, and the Calaveras channel to meet irrigation demands and for recharge. A crew of SEWD employees works seven days a week adjusting the heights of flashboard dams for irrigators and adjusting slidegates that control the water being diverted down Mormon Slough and the Calaveras River.

An order of the Reclamation Board allows the district to install flashboard dams on Mormon Slough after April 15[1] and requires removal before November 1. The SEWD installs 29 flashboard dams annually in Mormon Slough, the Calaveras River, and in Potter Creek.

SEWD's primary municipal-industrial diversion facilities are near Bellota and consist of the Calaveras Headworks, Bellota Weir, and the municipal-industrial intake for the water treatment plant.

The Calaveras Headworks comprises four concrete culverts and 4-foot square openings and slidegates on the upstream end (see Figure 2-3f). The channel capacity in the reach downstream is severely restricted due to its small cross section and dense overgrowth on its banks (USACE 1983). Two slidegates are operated during irrigation season to control flows down the Calaveras channel. The slidegates will remain open after irrigation season for recharge purposes. The slidegates will close once Podesta Reservoir spills, and flood control conditions occur (see Figure 2-3f). If spilling from Podesta Reservoir stops, the gates may be opened again for recharge.

SEWD serves 19 irrigation diverters and maintains five road crossings in the river upstream of Bellota Weir. The Calaveras County Water District diverts water for its Jenny Lind Water Treatment Facility downstream of New Hogan Dam and for approximately nine irrigation diverters between the facility and the San Joaquin County line.

Agricultural Diversions

The Department of Fish and Game Screen and Diversion Inventory Program located diversions in the Calaveras River and Mormon Slough in 1998 and 2000. Based on results from the 1998 and 2000 inventories, there are 143 pumps, slidegates, and screwgates in the Calaveras River. Maximum diversion capacity is known for 23 structures on the Calaveras River. Of the 67 pumps in Mormon Slough, maximum diversion capacity is known for one.

[1] The flashboards can be installed before April 15 with Reclamation Board approval

SEWD Municipal and Industrial Diversion Structure

SEWD operates municipal-industrial diversion facilities on the Calaveras River at Bellota Weir (see Figure 2-3f). These include the Calaveras Headworks, built in 1933; Bellota Weir, built in late 1940s; and the municipal-industrial water diversion facility, built in 1978. The 65-cfs capacity municipal-industrial diversion facility began diverting water in 1978 to SEWD's water treatment plant.

Bellota Weir is on Mormon Slough just downstream of the separation between the Calaveras River and Mormon Slough. It is a dam with removable checks and flow control slidegates at its face. The dam crest is 8 feet above the channel.

The intake to SEWD's municipal-industrial water supply system is just upstream of Bellota Weir. The design capacity of the intake and conveyance is 90 cfs (USACE 1983). The intake structure is fitted with a debris rack, but does not have fish screens installed. SEWD has installed a temporary fish screen at Bellota Weir, and is currently seeking funds for a permanent fish screen.

During the flood control period, water released from New Hogan Lake reaches Bellota Weir and is diverted to the water treatment plant. Floodflows are not released down the Calaveras channel. Only local runoff or overflow from Podesta Reservoir flows into the Calaveras River downstream of the Headworks.

Calaveras Downstream of the Calaveras Headworks

There are approximately 80 diversions on the Calaveras River downstream of the Calaveras Headworks. Surface water from the Calaveras River is available to diverters in years when enough water is available from New Hogan Dam. In years when water supplies are less, water may only flow down the Mormon Slough. If water supplies are exceptionally low, the Calaveras River channel and Mormon Slough are mostly dry, and diverters may resort to pumping groundwater to make up their irrigation demands.

Podesta Reservoir, a small reservoir that catches surface runoff, is privately owned and lies in a small drainage basin just north of the Calaveras River approximately one mile downstream of the Calaveras River and Mormon Slough split (see Figure 2-3f). It stores water for irrigation, but in the winter it releases water that is in excess of its approximate 3,000-af capacity to the Calaveras River channel. If water must be released from New Hogan Lake at the beginning of flood season to bring the reservoir down to its prescribed allowable flood storage capacity, some water may be diverted to the Calaveras channel for percolation into the local groundwater basin.

Mormon Slough/Stockton Diverting Canal

The Stockton Diverting Canal was built in 1910 to carry flows from Mormon Slough around the east side of the city of Stockton and back to the Calaveras River. In 1969 the USACE modified Mormon Slough from its confluence with the Stockton Diverting Canal upstream to Bellota Weir to convey additional floodflows. The 1969 project enlarged and realigned the existing channel to increase its capacity to the New Hogan Lake operation design objective of 12,500 cfs (USACE 1983).

Potter Creek

Potter Creek, a tributary channel to Mormon Slough, carries water throughout the irrigation season for adjacent farmland. Three flashboard dams and four road crossings are in the creek. Water is either pumped or diverted from Mormon Slough into Potter Creek during irrigation season via the Bellota pipeline or a 4,000-gallons-per-minute pump and an 8,000 gpm pump. Water flows from Potter Creek back into Mormon Slough at two points, just downstream of the old Southern Pacific Railroad bridge (see Figure 2-3h) and upstream of Panella dam (see Figure 2-3i). During the winter Potter Creek receives surface runoff, increasing flows in Mormon Slough.

gpm = gallons per minute

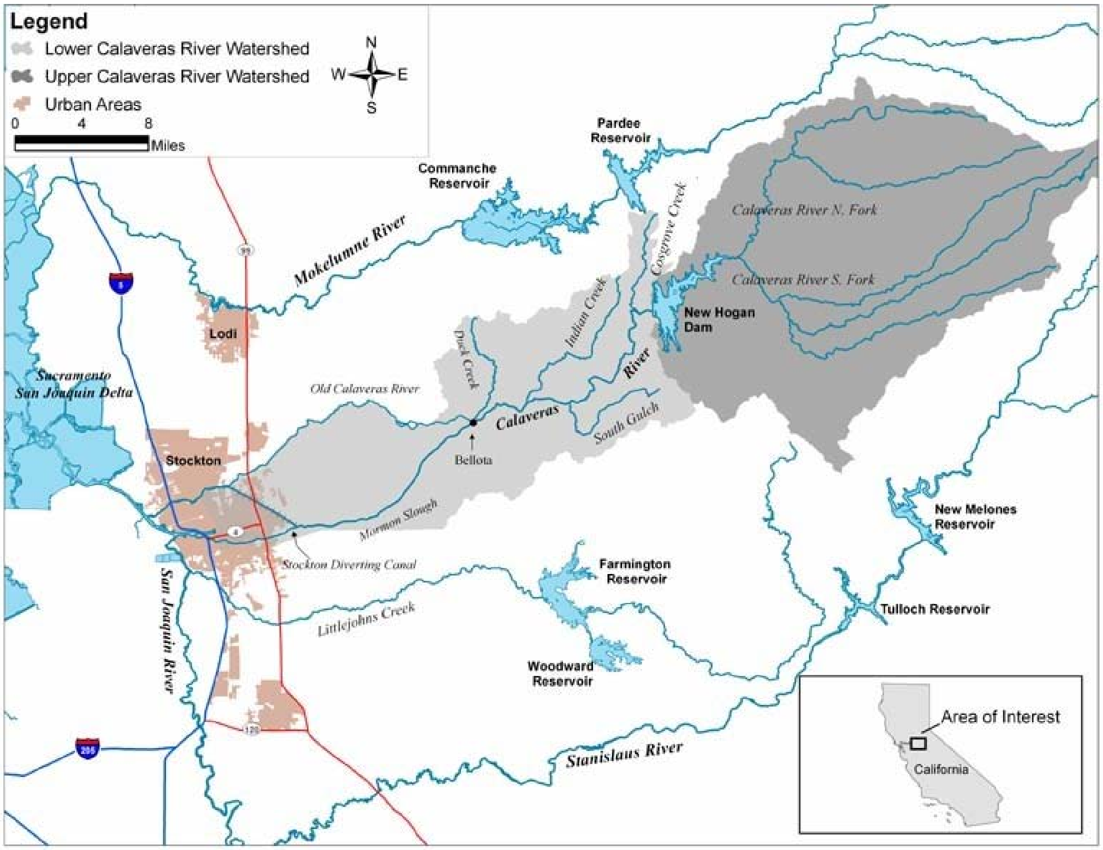
Mosher Creek

A small water control structure with a slidegate diverts water from the Calaveras River downstream of the Headworks into Mosher Creek for irrigators along the creek. Mosher Creek and the channel immediately north, Bear Creek, flow into a slough prior to entering the San Joaquin River (see Figure 2-1). Neither creek provides upstream access for fish to enter the Calaveras River downstream of the Headworks. Mosher Creek flows naturally only when it receives flow from surface runoff.

Chapter 2 Existing Hydrologic and Water Supply Operations

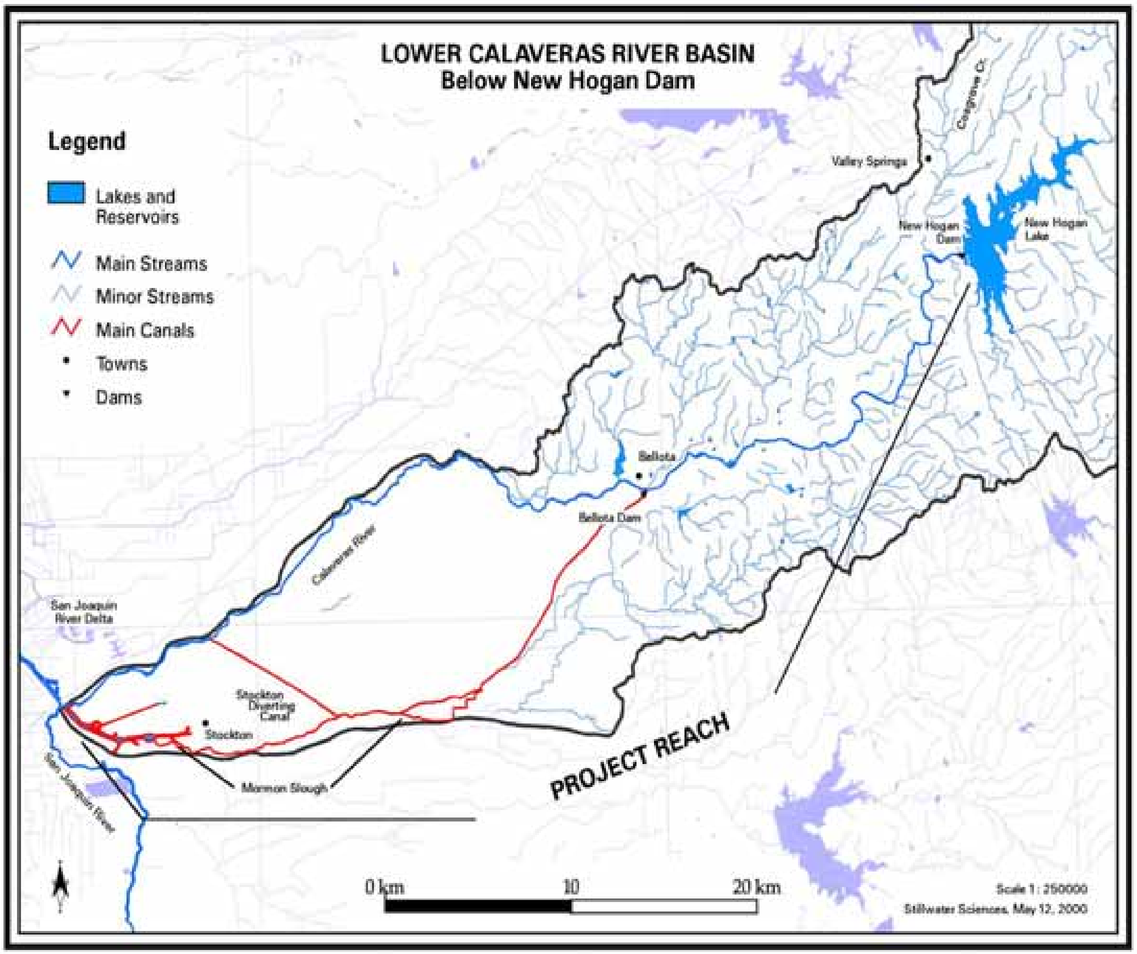
List of Figures

Figure 2-1. Calaveras River watershed



source: S.P. Cramer and Associates

Figure 2-2. Lower Calaveras River basin



Source: Stillwater Sciences

Figure 2-3a. Structure location—vicinity map

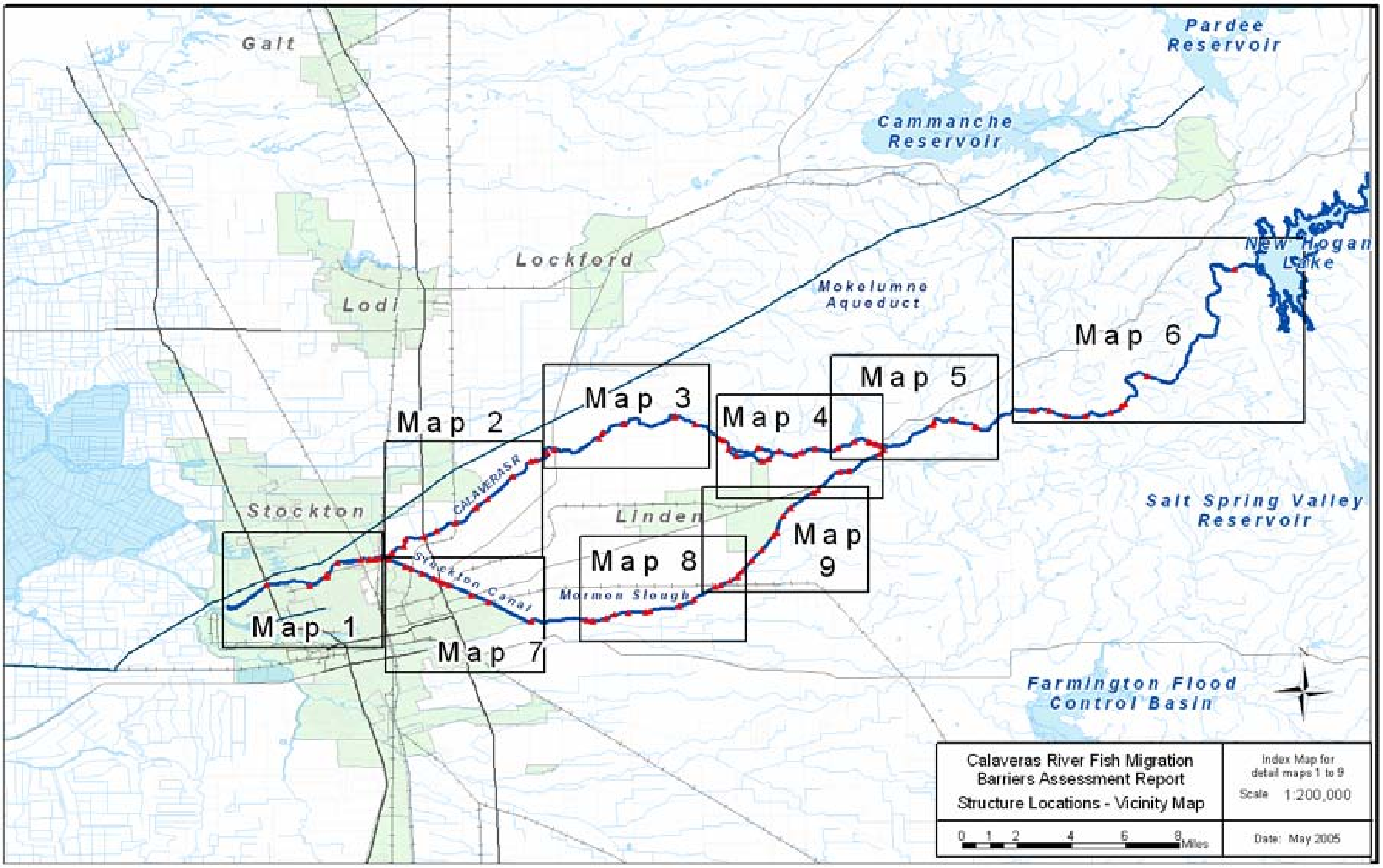


Figure 2-3b. Structure location—detail map 1

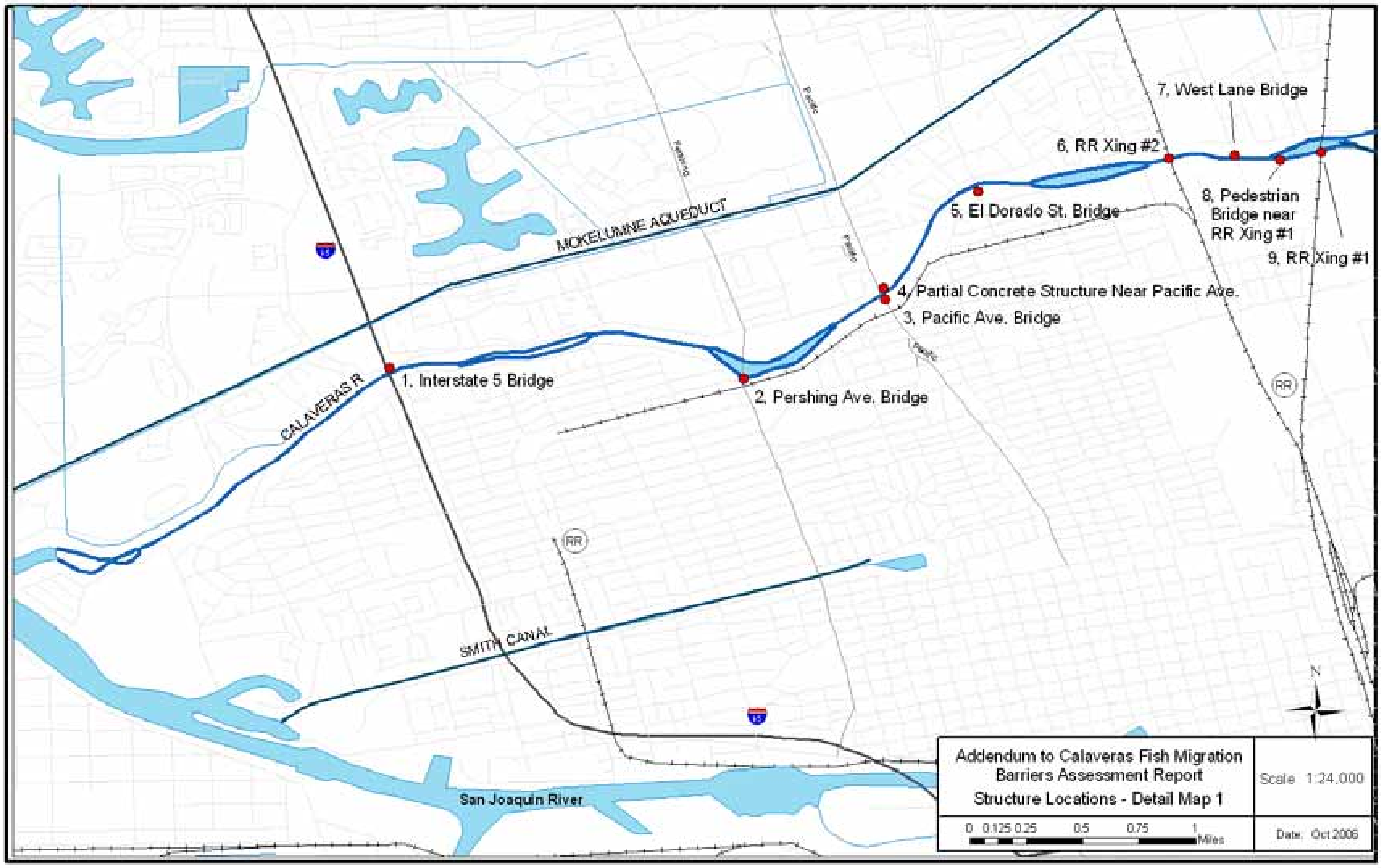


Figure 2-3c. Structure location—detail map 2

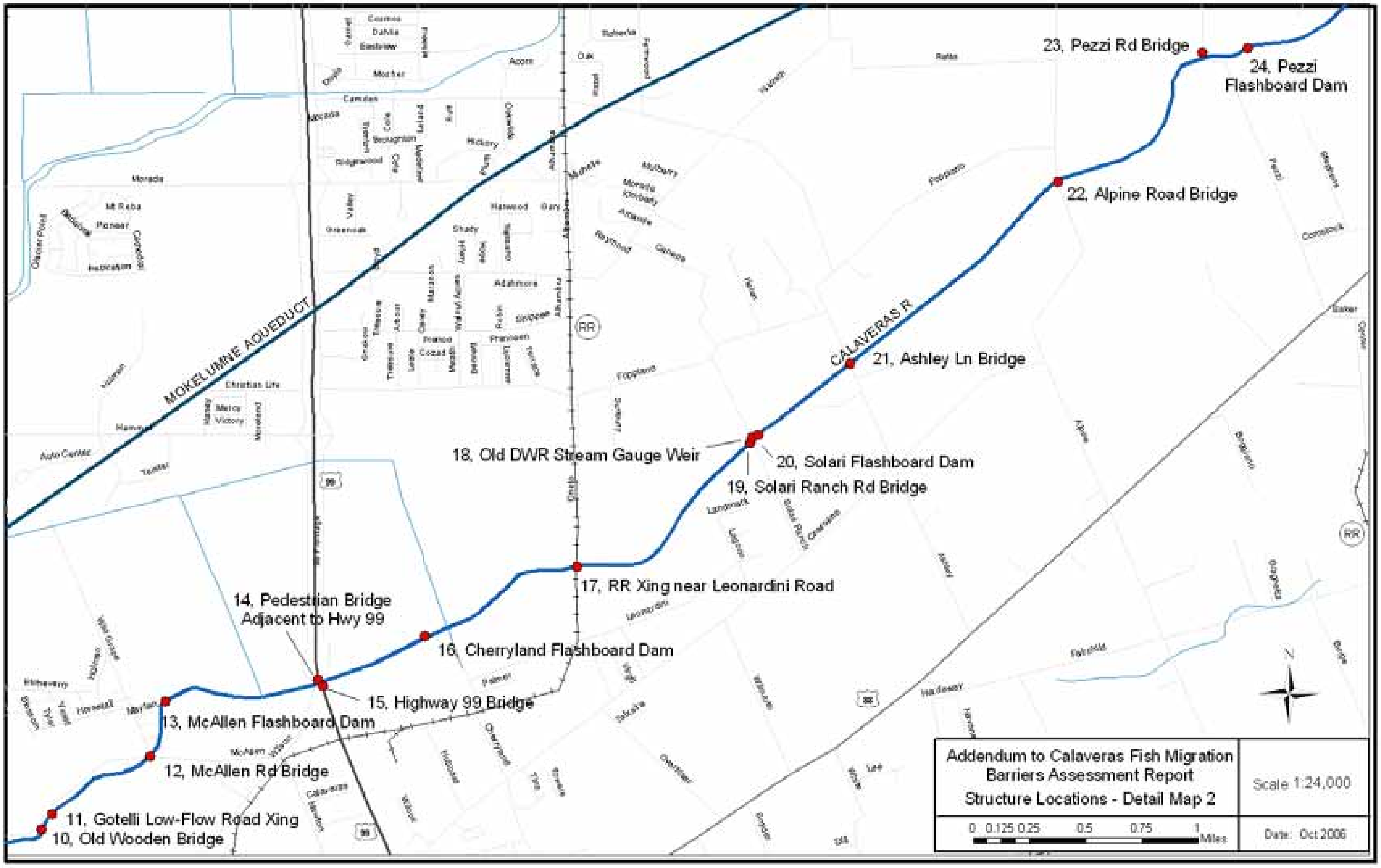


Figure 2-3d. Structure location—detail map 3

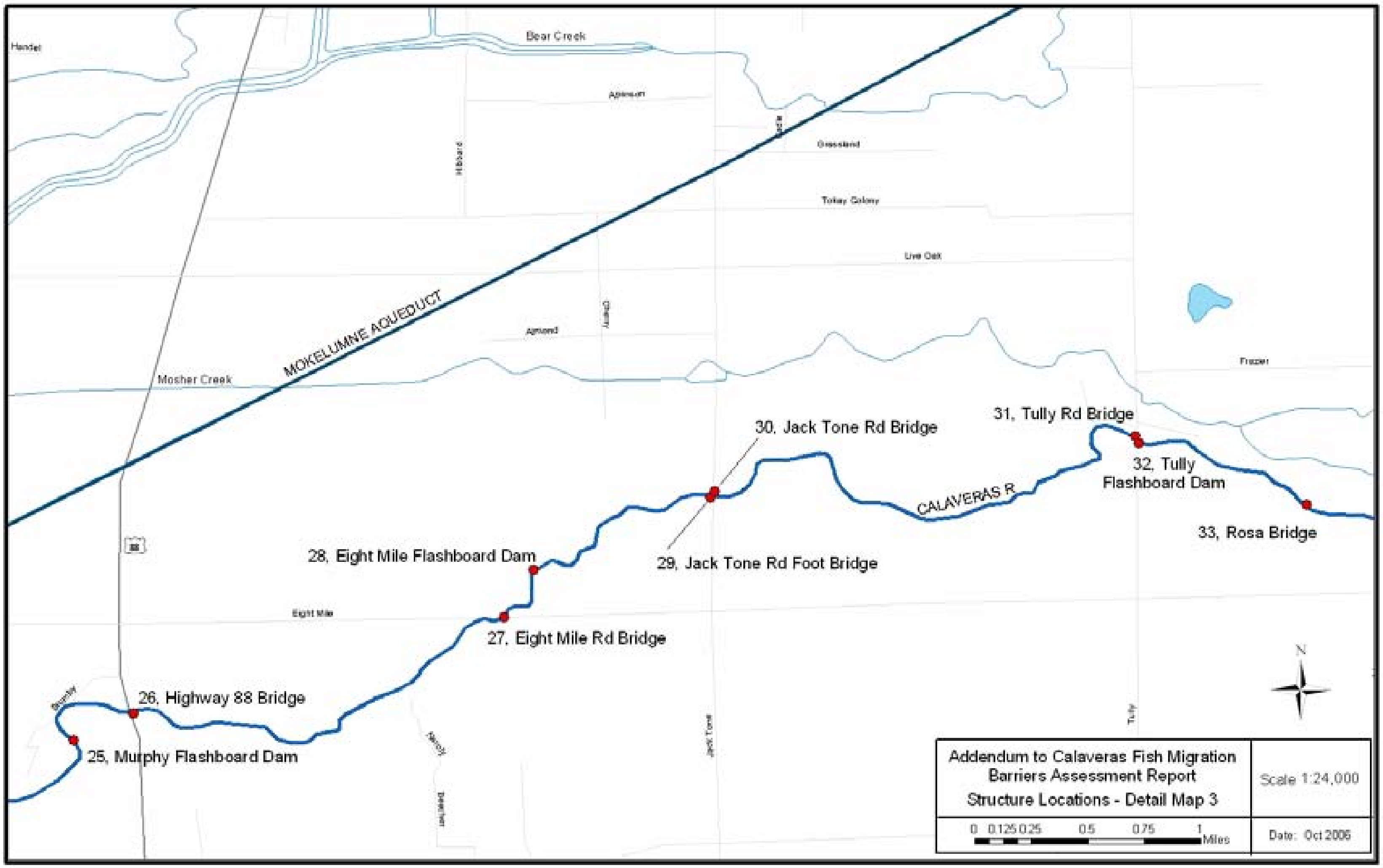


Figure 2-3e. Structure location—detail map 4

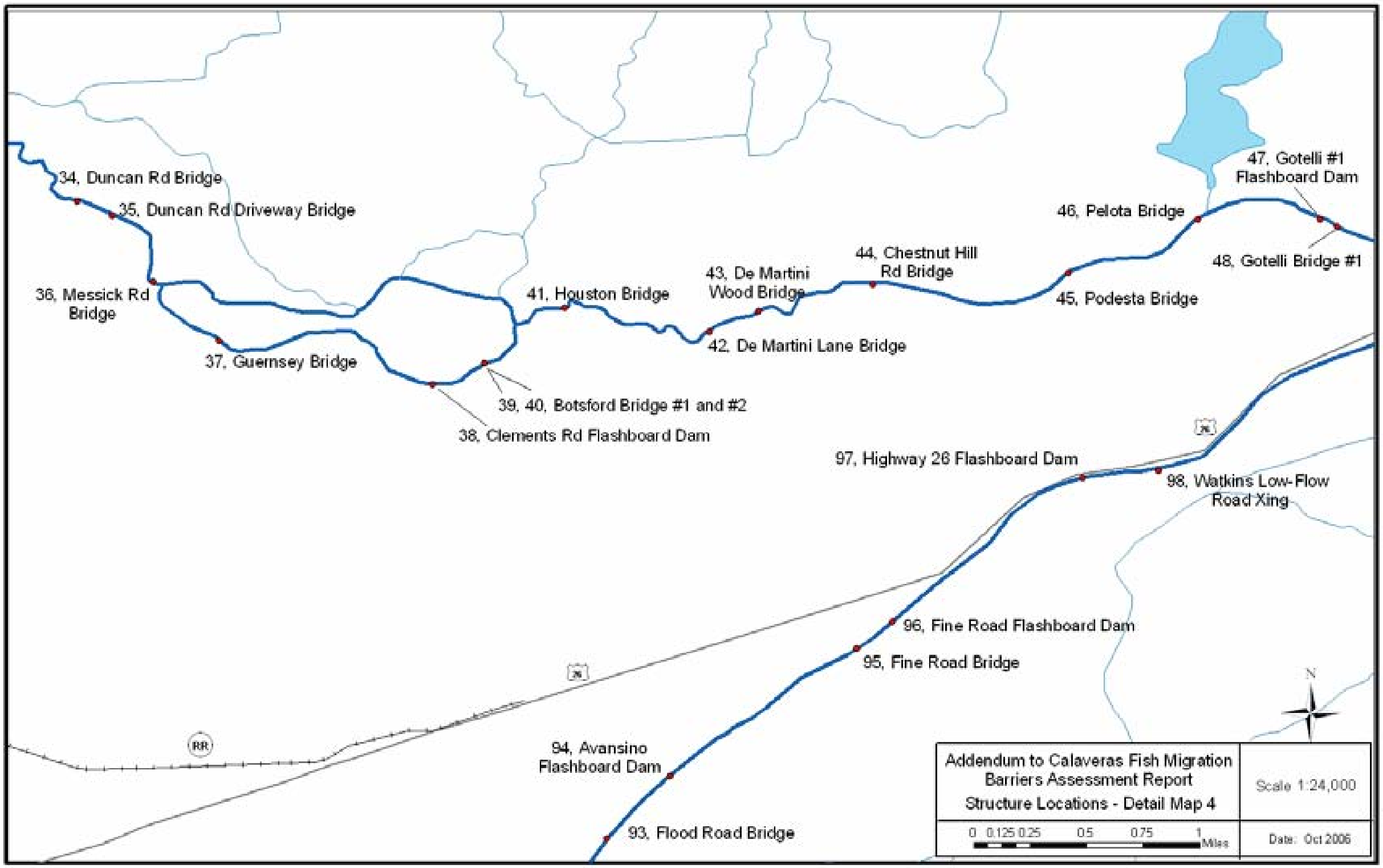


Figure 2-3f. Structure location—detail map 5

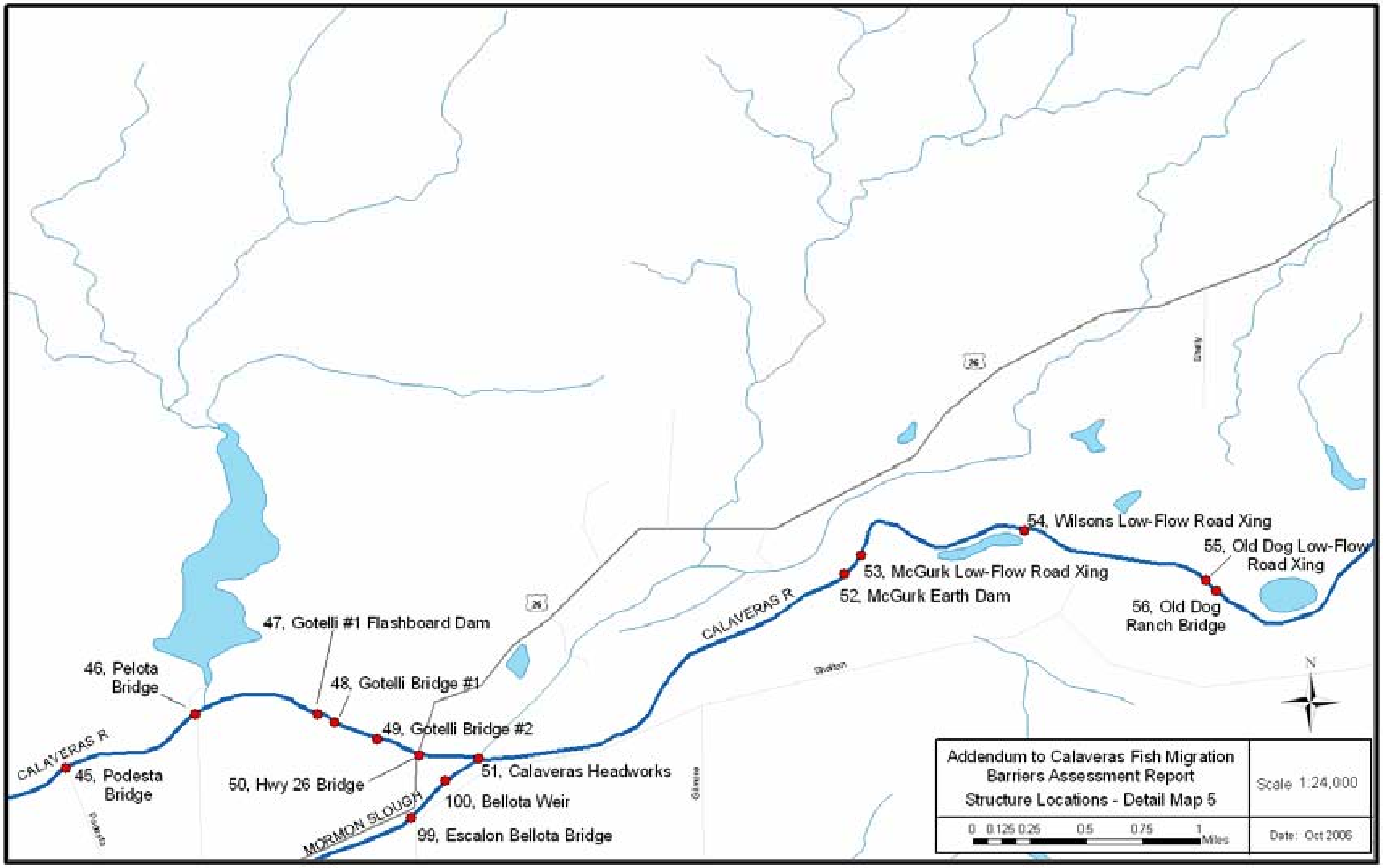


Figure 2-3g. Structure location—detail map 6

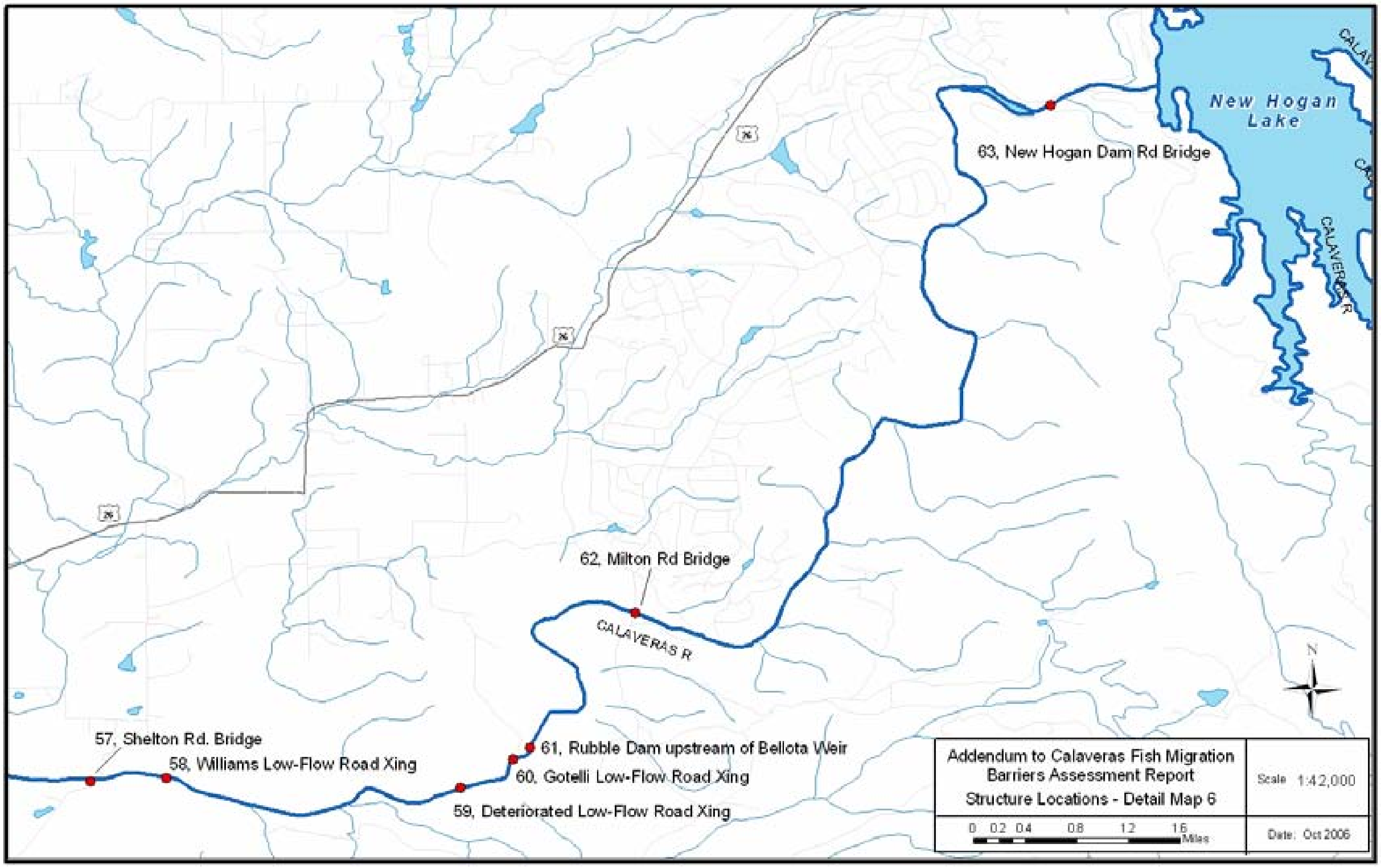


Figure 2-3h. Structure location—detail map 7

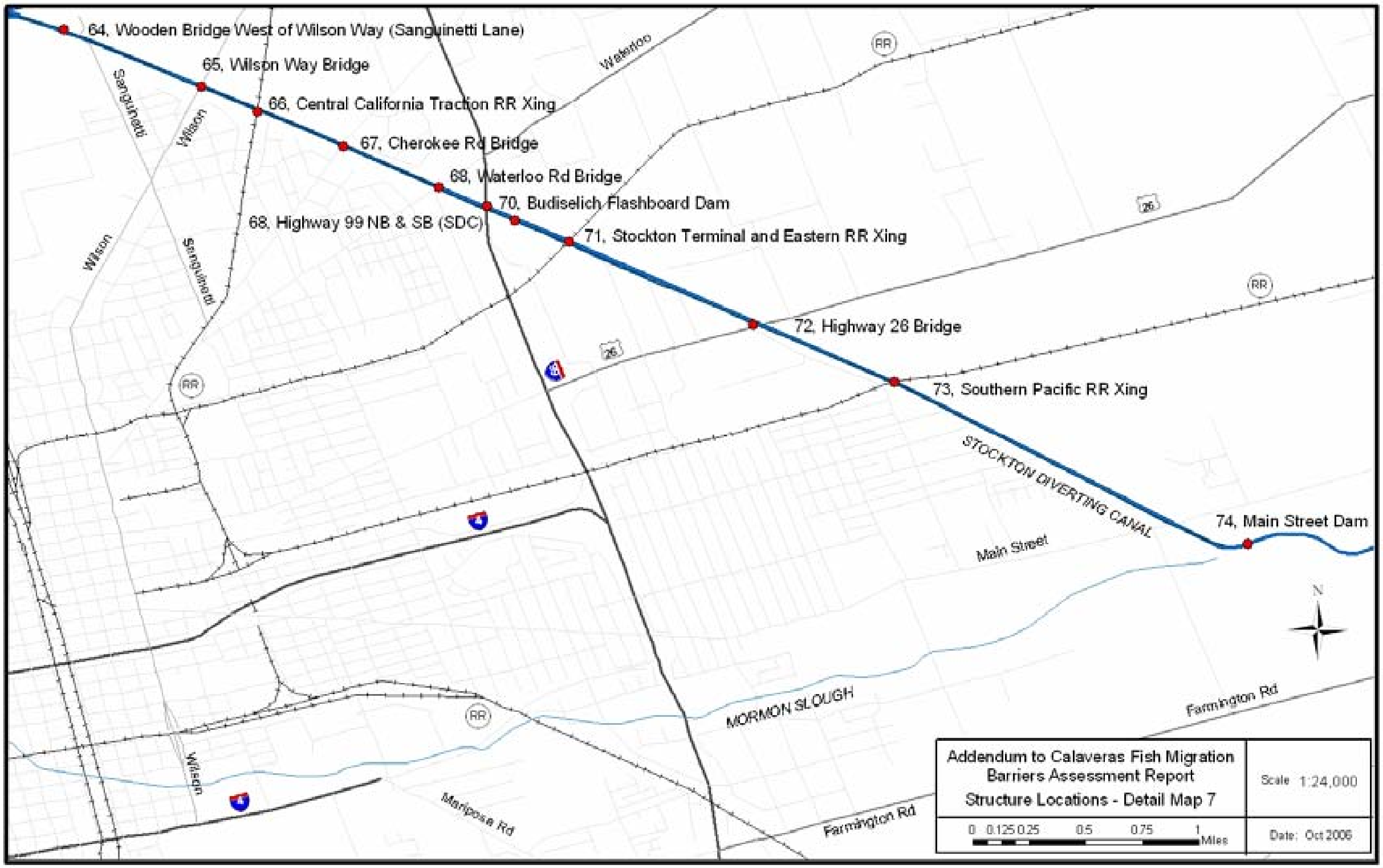


Figure 2-3i. Structure location—detail map 8

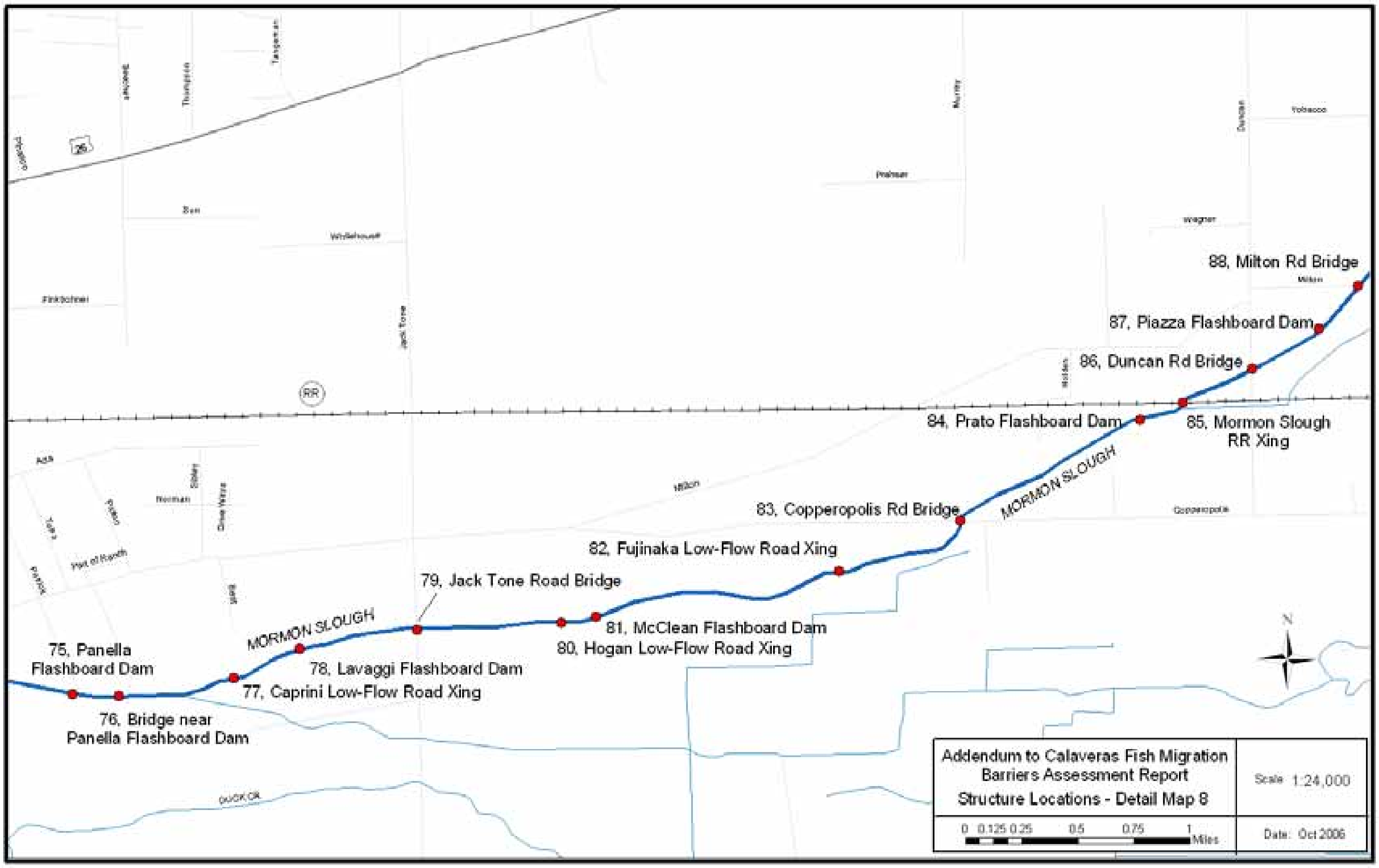


Figure 2-3j. Structure location—detail map 9

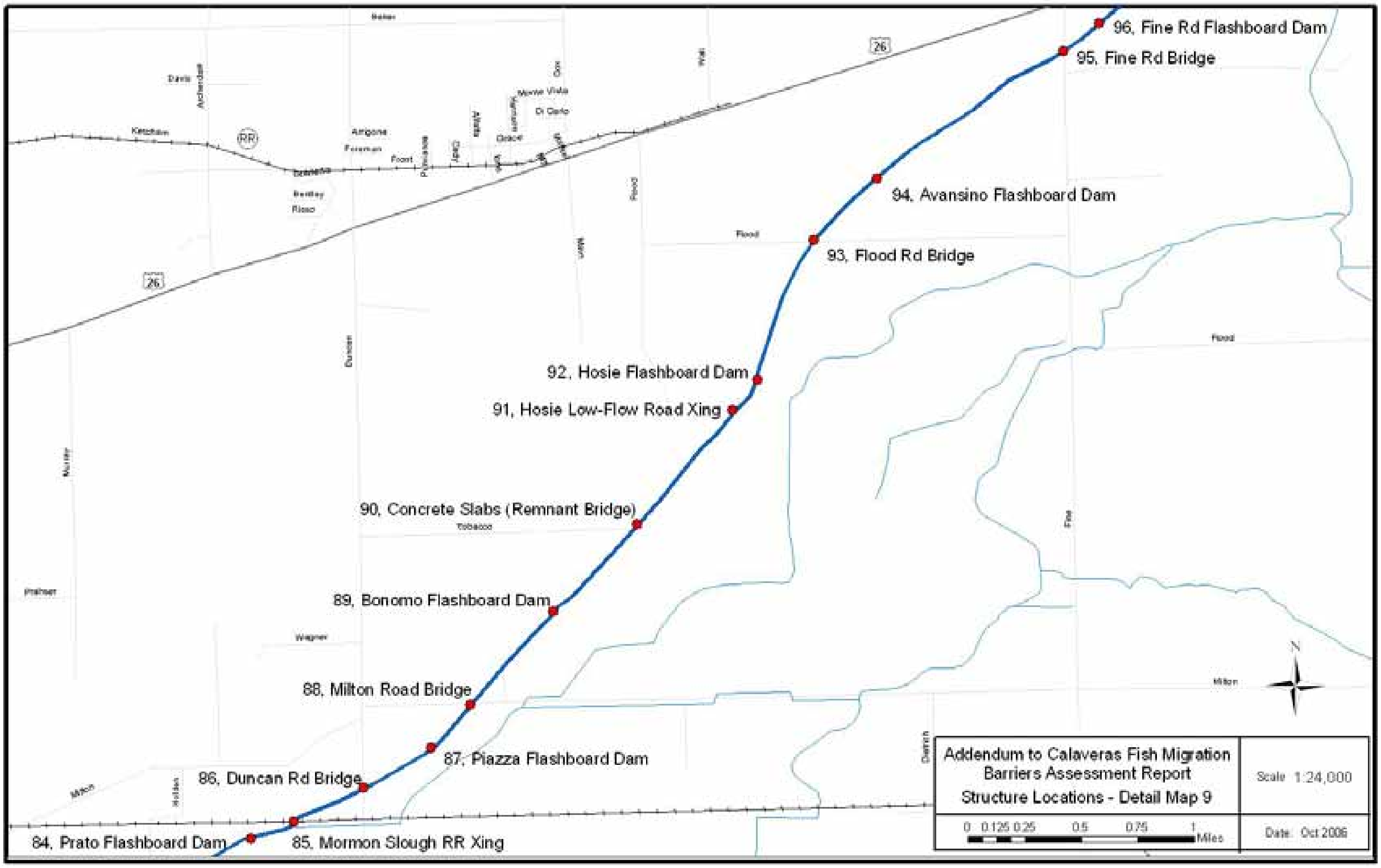


Figure 2-4. Stream gage locations

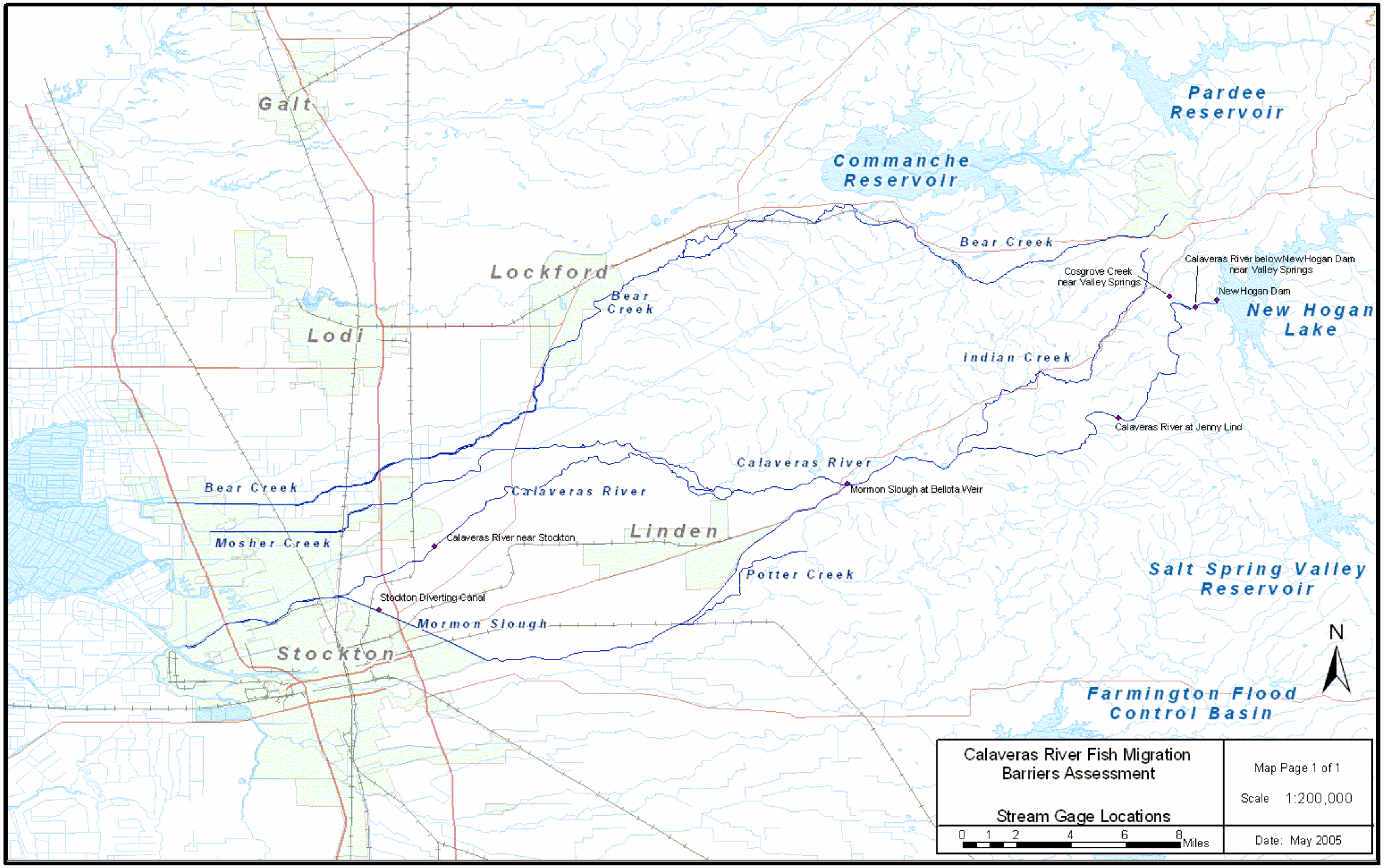
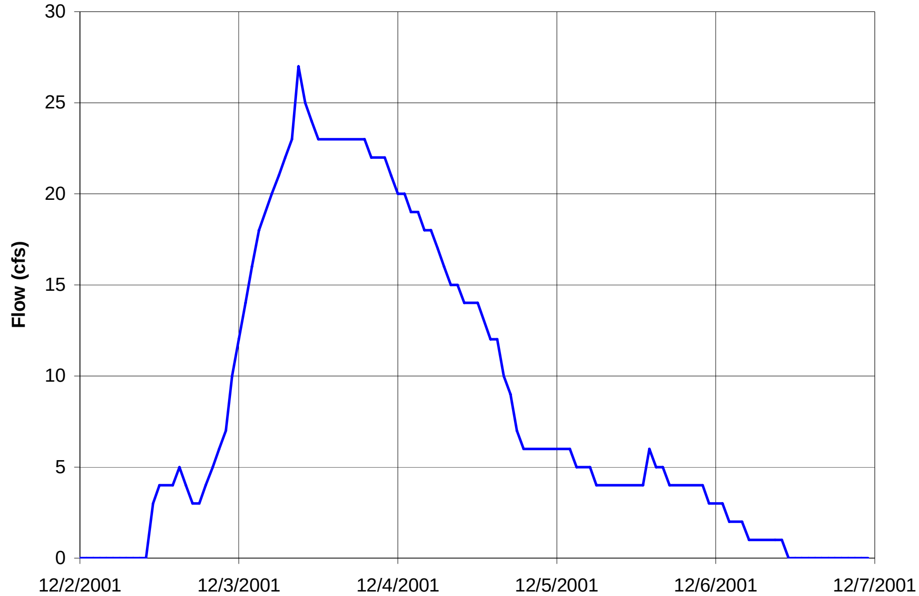


Figure 2-5. Hydrograph of Mormon Slough at Bellota Weir, 2–6 Dec 2001



Chapter 2 Existing Hydrologic and Water Supply Operations

List of Tables

Table 2-1. Distances for segments of the Calaveras River and associated channels

Segment	Distance (miles)	River miles
Calaveras River, Stockton Diverting Canal to mouth	5.2	5.2 to 0.0
Stockton Diverting Canal	4.9	4.9 to 0.0
Mormon Slough, Bellota Weir to Stockton Diverting Canal	13.4	25.1 to 11.6
Calaveras River, New Hogan Dam to Bellota Weir	19.0	44.0 to 25.1
Calaveras River, Calaveras Headworks to Stockton Diverting Canal	19.8	25.9 to 5.2

Table 2-2. Structures on the Calaveras River

Map ID No.	Structure name	Description	River mile
1	Interstate 5 Bridge	Bridge - Road	2.0
2	Pershing Avenue Bridge	Bridge - Road	3.2
3	Pacific Avenue Bridge	Bridge - Road	3.7
4	Partial Concrete Structure Near Pacific Avenue Bridge	Permanent Dam/Weir	3.9
5	El Dorado Street Bridge	Bridge - Road	4.5
6	Railroad Bridge #2	Bridge - Railroad	5.2
7	West Lane Bridge	Bridge - Road	5.5
8	Pedestrian Bridge near Railroad Bridge #1	Bridge - Pedestrian	5.6
9	Railroad Bridge #1	Bridge - Railroad	5.7
10	Old Wooden Bridge	Bridge - Road	6.1
11	Gotelli Low-flow Road Crossing	Low-flow Road Crossing	6.2
12	McAllen Road Bridge	Bridge - Road	6.9
13	McAllen Flashboard Dam	Flashboard Dam	6.9
14	Pedestrian Bridge adjacent to Highway 99	Bridge - Pedestrian	7.4
15	Highway 99 Bridge	Bridge - Road	7.4
16	Cherryland Flashboard Dam	Flashboard Dam	7.9
17	Railroad Bridge near Leonardini Road	Bridge - Railroad	8.6
18	Old DWR Stream Gauge Weir	Permanent Dam/Weir	9.5
19	Solari Ranch Road Bridge	Bridge - Road	10.1
20	Solari Flashboard Dam	Flashboard Dam	10.1
21	Ashley Lane Bridge	Bridge - Road	10.1
22	Alpine Road Bridge	Bridge - Road	11.1
23	Pezzi Road Bridge	Bridge - Road	11.9
24	Pezzi Flashboard Dam	Flashboard Dam	12.1
25	Murphy Flashboard Dam	Flashboard Dam	12.5
26	Highway 88 Bridge	Bridge - Road	13.1
27	Eight Mile Road Bridge	Bridge - Road	14.7
28	Eight Mile Flashboard Dam	Flashboard Dam	15.0
29	Jack Tone Road Foot Bridge	Bridge - Pedestrian	15.8
30	Jack Tone Road Bridge	Bridge - Road	15.8
31	Tully Road Bridge	Bridge - Road	17.8
32	Tully Flashboard Dam	Flashboard Dam	17.9
33	Rosa Bridge	Bridge - Road	18.6
34	Duncan Road Bridge #1	Bridge - Road	19.6
35	Duncan Road Driveway Bridge	Bridge - Road	19.8
36	Messick Road Bridge	Bridge - Road	20.1
37	Guernsey Bridge	Bridge - Road	20.6
38	Clements Road Flashboard Dam	Flashboard Dam	21.5

Map ID No.	Structure name	Description	River mile
39	Botsford Bridge #1	Bridge Road	21.7
40	Botsford Bridge #2	Bridge - Road	21.7
41	Houston Bridge	Bridge - Road	22.12
42	De Martini Lane Bridge	Bridge - Road	22.8
43	De Martini Wood Bridge	Bridge - Road	23.1
44	Chestnut Hill Road Bridge	Bridge - Road	23.6
45	Podesta Bridge #1	Bridge - Road	24.2
46	Pelota Bridge #1	Bridge - Road	24.8
47	Gotelli #1 Flashboard Dam	Flashboard Dam	25.4
48	Gotelli Bridge #1	Bridge - Road	25.4
49	Gotelli Bridge #2	Bridge - Road	25.5
50	Highway 26	Bridge - Road	25.8
51	Calaveras Headworks	Permanent Dam/Weir	25.9
52	McGurk Earth Dam	Permanent Dam/Weir	27.1
53	McGurk Low-flow Road Crossing	Low-flow Road Crossing	27.1
54	Wilsons Low-flow Road Crossing	Low-flow Road Crossing	28.0
55	Old Dog Low-flow Road Crossing	Low-flow Road Crossing	29.0
56	Old Dog Ranch Bridge	Bridge - Road	30.2
57	Shelton Road Bridge	Bridge - Road	31.0
58	Williams Low-flow Road Crossing	Low-flow Road Crossing	33.0
59	Deteriorated Low-flow Road Crossing	Low-flow Road Crossing	34.9
60	Gotelli Low-flow Road Crossing	Low-flow Road Crossing	35.3
61	Rubble Dam upstream of Bellota Weir	Permanent Dam/Weir	35.5
62	Milton Road Bridge	Bridge - Road	36.00
63	New Hogan Dam Road Bridge	Bridge - Road	42.9

Note: See Appendix E for latitude and longitude coordinates for each structure.

Table 2-3. Structures on the Stockton Diverting Canal

Map ID No.	Structure name	Description	River mile
64	Wooden Bridge West of Wilson Way	Bridge - Road	1.2
65	Wilson Way Bridge	Bridge - Road	1.2
66	Central California Traction Railroad Bridge	Bridge - Railroad	1.1
67	Cherokee Road Bridge	Bridge - Road	0.7
68	Waterloo Road Bridge	Bridge - Road	2.3
69	Highway 99 Bridge	Bridge - Road	2.1
70	Budiselich Flashboard Dam	Flashboard Dam	2.1
71	Stockton Terminal and Eastern Railroad Bridge	Bridge - Railroad	2.1
72	Highway 26 Bridge	Bridge - Road	3.0
73	Southern Pacific Railroad Bridge	Bridge - Railroad	3.5

Note: See Appendix E for latitude and longitude coordinates for each structure.

Table 2-4. Structures on the Mormon Slough

Map ID No.	Structure name	Description	River mile
74	Main Street Flashboard Dam	Flashboard Dam	4.9
75	Panella Flashboard Dam	Flashboard Dam	6.6
76	Bridge Near Panella Flashboard Dam	Bridge - Road	6.6
77	Caprini Low-flow Road Crossing	Low-flow Road Crossing	7.3
78	Lavaggi Flashboard Dam	Flashboard Dam	7.5
79	Jack Tone Road Bridge	Bridge - Road	8.0
80	Hogan Low-flow Road Crossing	Low-flow Road Crossing	8.4
81	McClean Flashboard Dam	Flashboard Dam	8.5
82	Fujinaka Low-flow Road Crossing	Low-flow Road Crossing	9.5
83	Copperopolis Road Bridge	Bridge - Road	10.0
84	Prato Flashboard Dam	Flashboard Dam	10.4
85	Mormon Slough Railroad Bridge	Bridge - Railroad	11.1
86	Duncan Road Bridge	Bridge - Road	11.2
87	Piazza Flashboard Dam	Flashboard Dam	12.0
88	Milton Road Bridge	Bridge - Road	12.0
89	Bonomo Flashboard Dam	Flashboard Dam	12.2
90	Concrete Slabs (Remnant Bridge)	Permanent Dam/Weir	12.7
91	Hosie Low-flow Road Crossing	Low-flow Road Crossing	13.2
92	Hosie Flashboard Dam	Flashboard Dam	13.4
93	Flood Road Bridge	Bridge - Road	14.0
94	Avansino Flashboard Dam	Flashboard Dam	14.4
95	Fine Road Bridge	Bridge - Road	15.0
96	Fine Road Flashboard Dam	Flashboard Dam	15.6
97	Highway 26 Flashboard Dam	Flashboard Dam	16.6
98	Watkins Low-flow Road Crossing	Low-flow Road Crossing	16.9
99	Escalon Bellota Bridge	Bridge - Road	18.0
100	Bellota Weir	Permanent Dam/Weir	25.1

Note: See Appendix E for latitude and longitude coordinates for each structure.

Table 2-5. Gages on the Calaveras River

Gage name	Number	Period of record
Jenny Lind	11309500	1907-1966
Calaveras River downstream of New Hogan Dam near Valley Springs	11308900	1961-1992
New Hogan Dam	NHG	1964-present
Mormon Slough at Bellota	B02560, MRS	1948-1975, 1988-present
Stockton Diverting Canal	B02580	1944-1982
Calaveras River near Stockton	B02520	1925-1987
Cosgrove Creek near Valley Springs	11309000	1929-1969, 1990-present

Note: Gage numbers starting with "B" are DWR gage numbers. NHG and MRS currently operated by the US Army Corps of Engineers. Other numbers belong to US Geological Survey.

Table 2-6. New Hogan Dam allowed water storage

Time period	Allowable storage (acre-feet)
June 8 through September 30	Up to 317,100
October 1 through December 1	Linearly reduced from 317,100 to152,000
December 1 through January 1	152,000
January 1 through March 20	Depending on rainfall quantities, linearly increased from 152,000 to 217,100
March 20 through June 8	Depending on rainfall quantities, linearly increased from 152,000 to 317,100

Source: SEWD 2001

Table 2-7. Releases from New Hogan for diversion at Bellota Weir: Normal (wet) year operations

Time period	Average daily diversion amounts (cubic feet per second)
November 1 through March 31	20 to 50 cfs for municipal & industrial use
April 1 through October 31	5 to 70 cfs for municipal & industrial use 80 to 230 cfs for agricultural use

Data provided by Stockton East Water District

Table 2-8. Releases from New Hogan for diversion at Bellota Weir: Dry year operations

Time period	Average daily diversion amounts (cubic feet per second)
November 1 through March 31	1 to 50 cfs for municipal & industrial use
April 1 through October 31	1 to 70 cfs for municipal & industrial use 0 to 75 cfs daily for agricultural use

Data provided by Stockton East Water District

Chapter 3 Biological Conditions

Contents

Blank page for 2-sided printing

Chapter 3
Biological Conditions

Within the Calaveras River watershed, anadromous fish have access to 38 miles of the river between New Hogan Dam and the San Joaquin River via Mormon Slough and the Stockton Diverting Canal. There are 36 miles of river between New Hogan Dam and the San Joaquin River via the Calaveras River (Figure 3-1). These two channels can provide suitable salmonid spawning and rearing habitat.

Figure 3-1. Lower Calaveras River basin

Fish Populations

Calaveras River Fish Populations

Prior to the completion of New Hogan Dam, the fishery of the Calaveras River watershed comprised a variety of native and introduced species. Native species included Sacramento pike-minnow and other minnows, *Oncorhynchus mykiss* and *O. tshawytscha* (Chinook salmon). Introduced species downstream of New Hogan Dam include American shad, several species of black bass, sunfish, and catfish. More than 20 species of resident fish and migratory anadromous fish inhabit the Calaveras River (USACE 1989).

[USACE] US Army Corps of Engineers. 1989. Draft Environmental Assessment Calaveras River Reconnaissance Study for Flood Control. Sacramento District, Corps of Engineers.

Salmonid Biology Background

The genus *Oncorhynchus*, within the family Salmonidae, contains six species of salmon, two species of trout that can exhibit both resident and anadromous lifecycles, and several species of trout. Salmon are those species whose females (and usually males) die after spawning and generally exhibit anadromous behavior. Anadromous fish are those that are hatched in fresh water, travel to the ocean as juveniles where they remain for most of their adult lives, and return to fresh water to spawn. The two species that can exhibit both resident and anadromous lifecycles and can spawn multiple times are cutthroat trout and rainbow trout. Trout are species originating from anadromous forms that are now completely landlocked (Moyle 2002). The Chinook salmon of the Sacramento–San Joaquin River system are separated into four runs: winter-run, fall-run, late-fall run, and spring-run. *O. mykiss* (see sidebar) are the most abundant and widely distributed native salmonid in western North America. They have adapted to a wide variety of habitats and have flexible life histories (Moyle 2002).

Moyle, Peter B. 2002. Inland Fishes of California. University of California Press. Berkeley, CA.

Oncorhynchus mykiss is used throughout this report because various agencies are not in agreement regarding which form of trout (the resident rainbow, or anadromous steelhead) are present in the segment of the Calaveras River discussed in this report.

The focus of this report is on assessing fish passage, and we are leaving it to other agencies to determine the form of *O. mykiss* present in the river.

The Central Valley fall-run Chinook has always been the most abundant run, and occurred in all major tributaries including the Calaveras River (Moyle 2002). Due to large dam construction, spring-run populations in the San Joaquin system have been lost. Fall-run Chinook salmon have the potential to replace a portion of the displaced spring-run (Moyle 2002). Fall-run Chinook salmon are adapted for spawning and rearing in the lower reaches of rivers and their tributaries during the wet season. They move upstream during the late summer and fall and typically spawn within weeks of arrival to spawning grounds. Juveniles will emerge in the late winter to early spring; start to move downstream within a few months to main stem rivers or estuaries prior to heading out to sea. This timing strategy allows the fall-run to use spawning and rearing areas in the valley reach of rivers that would otherwise be too warm to support salmon in the summer months (Moyle 2002). This strategy leads to a high rate of straying, where individuals will deviate from their natal streams to take advantage of favorable spawning conditions elsewhere. This is an adaptive mechanism allowing colonization of new areas and providing more of a genetic mix to occur (Moyle 2002).

In California, *O. mykiss* were originally in all permanent streams from the Klamath River basin to San Diego County. *O. mykiss* found in the Calaveras River are from the Central Valley Evolutionarily Significant Unit (ESU) and federally listed as threatened (US Department of Commerce 1998). In the Central Valley, *O. mykiss* enters fresh water in August, with peak numbers in September and October. At this point the fish will hold until flows are high enough to allow movement into the tributaries to spawn. Typically, the anadromous form of *O. mykiss* will spend one to four years in fresh water and one to three years in salt water before returning to spawning grounds. However, some fish may remain in fresh water for their entire lives, and others will migrate to or from the ocean in less than a year. Unlike salmon, *O. mykiss* does not necessarily die after spawning. Repeat spawning does occur although the rates are believed to be relatively low and vary among populations (CALFED 1999; Moyle 2002). The anadromous form of *O. mykiss* may live up to 9 years, but rarely do resident *O. mykiss* live to 6 years (Moyle 2002). Like salmon, trout tend to return to natal stream to spawn; however, certain individuals in a population are prone to stray, helping to ensure gene flow and re-establishing extinct or depleted populations (Moyle 2002).

ESU = Evolutionarily Significant Unit

U.S. Department of Commerce. 1998. NOAA's National Marine Fisheries Service. 50 CFR Part 227. Endangered and Threatened Species; Threatened Status for Two ESU's of *O. mykiss* in Washington, Oregon, and California.

CalFed Bay-Delta Program. 1999. Monitoring, Assessment, and Research on Central Valley *O. mykiss*: Status of Knowledge, Review of Existing Programs, and Assessment of Needs, Interagency Ecological Program *O. mykiss* Project Workteam. Developed for the CalFed Comprehensive Monitoring Assessment and Research Program, Technical Appendix VII – A – 11. March

Calaveras River Salmonid Populations

Little is known about Chinook salmon and *O. mykiss* migration timing in the Calaveras River. The Fishery Foundation of California (FFC) monitored timing and abundance of migrating adult and juvenile salmon and *O. mykiss* in the fall through spring of 2001–2002 and 2002–2003. Flows in both periods were so low or sporadic that surveys of adult migration timing were inconclusive. Once flows from rain occurred, adults attempted to come into the lower channels, but it is unknown how long fish had been waiting. It was not possible to establish the spawning migration peak or duration as flows were discontinuous in the lower parts of the system. The results of these surveys are incorporated into the US Fish and Wildlife Service (USFWS) Calaveras River Salmon and *O. mykiss* Life History Study. The First Year Report for the Life History Study has been revised and is available at www.delta.dfg.ca.gov/afrp/documents/Final_Report_mrs091004_jrr091704.pdf.

FFC = Fishery Foundation of California

USFWS = US Fish and Wildlife Service

[DFG] California Department of Fish and Game. 1993. Restoring Central Valley Stream: a plan for action. Inland Fisheries Division. Compiled by F.L. Reynolds, T.J. Mills, R. Benthin, and A. Low. Report for public distribution, November 10, 1993. Inland Fisheries Division, Sacramento.

Stillwater Sciences. 2004. Lower Calaveras River Chinook Salmon and Steelhead Trout Limiting Factors Analysis. First Year Report (Revised). Prepared for Fishery Foundation of California. Available at: www.delta.dfg.ca.gov/afrp/documents/Final_Report_mrs091004_jrr091704.pdf

Adult Chinook salmon have been observed in the Calaveras River between November and July. Spawning has been observed in fall, spring, and early summer months. The California Department of Fish and Game (DFG 1993) documented adult Chinook salmon in the Calaveras River in 1972, 1975, 1976, 1978, 1982, and 1984. Juvenile salmon have been observed in the river between February and June (DFG 1993).

DFG = California Department of Fish and Game

Local anglers reported catching *O. mykiss* from the river in spring and early summer in the 1930s, November to January in the 1940s, 1960s, and 1970s, and in spring in 1998. DFG documented *O. mykiss* in the river downstream of New Hogan Dam in March 2000. Biologists of the FFC found live and dead adult *O. mykiss* in Mormon Slough in late March and early April 2002 along with *O. mykiss* redds, or nests, in riffles downstream of Bellota Weir (unpublished data). In October 2002, the FFC and S.P. Cramer and Associates found dead adult *O. mykiss* in both Mormon Slough and the Calaveras River downstream of the Calaveras Headworks, presumably having over-summered but then died when the irrigation season ended and flows stopped (unpublished data). FFC snorkel surveys of the Calaveras River downstream of New Hogan Dam in 2002 indicate a large population of *O. mykiss* exists and naturally reproduces in the reach (unpublished data).

Beginning in spring 2002, Stockton East Water District (SEWD) engaged S.P. Cramer and Associates to sample downstream migrant fish with a rotary screw trap at Shelton Road, upstream of Bellota Weir. They sample annually from January to May. Downstream migrating smolt size *O. mykiss* have been caught from January to May. Six juvenile Chinook salmon were captured during 2002, but none were captured during sampling in 2003 and 2004. In May 2003, the FFC deployed fyke nets in the Calaveras channel and in Mormon Slough downstream of Bellota Weir and the Calaveras Headworks. No juvenile salmon were caught in the fyke nets; however, juvenile *O. mykiss* from 40 to 100 mm were caught indicating that some young *O. mykiss* pass downstream of Bellota Weir and the Calaveras Headworks as they disperse downstream from spawning grounds to feed and grow, or rear. None of the young-of-the-year *O. mykiss* could reach tidewater because the channels were disconnected farther downstream (FFC, unpublished data). Water temperatures downstream of the weirs in the two channels had reached stressful levels (>64 ^{o}F). According to Moyle (2002), optimal temperature for growth and survival are between 55 ^{o}F and 64 ^{o}F, anything greater than 64 ^{o}F can lead to disease or mortality.

SEWD = Stockton East Water District

S.P. Cramer and Associates continue to operate a rotary screw trap at Shelton Road and collect samples three to four days a week during sampling season. Current data for the 2003-2004, 2004-2005, and 2005-2006 seasons can be viewed on the outmigration reports at www.calaverasriver.com/sewd_fisheries_reports.htm.

Shelton Road outmigration reports: www.calaverasriver.com/sewd_fisheries_reports.htm

Salmonid Migration Timing for the Calaveras River

The Fish Passage Improvement Program developed expected migration time periods for *O. mykiss* and fall-run Chinook salmon for the Calaveras River based on information from the Tuolumne River, Mokelumne River, and data specific to Calaveras River discussed above. Input from DFG, USFWS, and the National Marine Fisheries Service is included in the expected migration time periods table (Table 3-1). The agencies agreed to use the migration periods for the purposes of this study.

Table 3-1. Expected migration time periods for *O. mykiss* and fall-run Chinook salmon in the Calaveras River

Tables 3-2 and 3-3 list migration periods for the Tuolumne River and Mokelumne River, respectively. Depending on location, Tuolumne River is approximately 40 miles south of Calaveras River, and Mokelumne River is approximately 20 miles north of Calaveras River.

Table 3-2. Generalized life history timing of fall-run Chinook salmon in the San Joaquin River basin (Tuolumne River)

Table 3-3. Life history timing of fall-run Chinook salmon and *O. mykiss* in the Mokelumne River

Table 3-4 lists Chinook salmon migration survey observations for the 2001-2002 adult migration season. Table 3-5 lists Chinook salmon surveyed in Mormon Slough during the 2003-2004 spawning season; Table 3-6 does the same for *O. mykiss*.

Table 3-4. Fall 2001 and winter 2002 salmon migration survey results

Table 3-5. Fall 2003 and winter 2004 salmon migration survey results from Mormon Slough

Table 3-6. Fall 2003 and winter 2004 *O. mykiss* migration survey results from Mormon Slough

Habitat Conditions

Riverine Habitat Conditions

The Calaveras River downstream of the Headworks (the flow control structure on the river) may have no flows other than tributary inputs from November through mid-April. It is a moderately confined channel with overgrown vegetation, particularly blackberries, and has potential for bank undercutting and erosion with increased flows (personal observation in 2005 by M. Hendrick of DWR). The Calaveras River downstream of Stockton Diverting Canal receives urban runoff from storm outlets delivering potential contaminants such as oils and hydrocarbons.

Hendrick, Michael. DWR. 2005. hendrick@water.ca.gov

Salmonid rearing habitat upstream of Bellota Weir is excellent (Stillwater Sciences 2004). The Calaveras River upstream of Bellota Weir and the Headworks has year-round flows, temperatures cold enough to sustain a cold-water fishery, vegetation ranging from orchards to riparian forest and upland grasslands, and receives runoff that may contain nutrients, bacteria, and sediment from point and nonpoint sources. Salmonid spawning and rearing habitat studies upstream of Bellota Weir have been competed and include a limiting factors analysis (Stillwater Sciences 2004).

Calaveras River

In 2004, Stillwater Sciences studied what biotic and abiotic factors are responsible for limiting the production of Chinook salmon and *O. mykiss* on the Calaveras River downstream of New Hogan Dam. Stillwater Sciences hypothesized that habitat is sufficient to support self-sustaining populations of fall and spring runs of Chinook salmon and populations of *O. mykiss.* The analysis also identified fish passage barriers as the principal limiting factor to adult upstream migration. The Calaveras River has habitat qualities indicating the potential for restoring an anadromous fishery. This includes a 22-feet-per-mile gradient, numerous riffles, and pools. There is spawning gravel, and a dense riparian canopy (USFWS 1993, CALFED 2000).

[USFWS] US Fish and Wildlife Service. 1993. Memorandum. From Wayne S. White, Field Supervisor, Sacramento Field Office, Sacramento, California to David Lewis, Regional Director, Bureau of Reclamation, Sacramento. Jan 28

Calfed Bay-Delta Program. 2000. Final Programmatic EIS/EIR. Ecosystem Restoration Program. Volume II. Sacramento. July

The river downstream of New Hogan Dam has several distinct reaches.

- River miles 44 to 43, immediately downstream of New Hogan Dam to the Quarry Road Bridge: A dense riparian corridor borders the river along this reach providing shaded riverine habitat on both sides of the river (Phil Holcomb. USAC. pers comm August 2, 2005). There is considerable floodplain habitat available in this river reach. In this reach, the river varies between 60 feet and 81 feet wide. The river valley between the Dam Road on the right bank and the opposite side of the valley is about 100 yards. Large cobble deposits line the left bank and a cobble and gravel bar supporting riparian vegetation extends about 100 yards downstream. An oak woodland habitat extends 10 to 20 yards beyond the riparian vegetation (Holcomb pers comm 2005). The vegetation cover provides brush and woody debris to the river. The water depth in this reach varies between 3 and 15 feet with one glide being 50 feet deep. This reach is characterized by a steep gradient, the elevation drops from 565 feet to 530 feet (Jim Inman. S.P. Cramer and Associates. pers comm

Holcomb, Phil. USACE. August 2, 2005. Philip.holcomb@usace.army.mil

Inman, Jim. S.P. Cramer and Associates. Personal communication. August 2005. inman@spcramer.com

August 2005). Several riffles provide habitat for *O. mykiss*. The river substrate consists primarily of gravels and sands.

- River miles 43 to 36, Quarry Road Bridge to Jenny Lind Bridge: Known as the canyon reach, this reach begins 1 mile downstream of New Hogan Dam and flows through a mixed conifer forest bordered by pine woodland, oak woodland, chaparral, and annual grassland. A dense riparian corridor borders the river along this reach (USFWS 1998). This reach from miles 43 to 36 has the steepest gradient downstream of the dam with elevation decreasing 274 feet from 530 feet to 256 feet. The reach is characterized by steep bedrock walls that confine and define the river valley making habitat difficult to describe. Most of the substrate is bedrock and cobble. J.D. Wickert (USFWS. 2005. pers comm August 2005) reports that this reach provides excellent habitat for *O. mykiss* with fair amounts of gravel retained and good structural heterogeneity, including a high concentration of woody debris.
- River miles 36 to 31, Jenny Lind Bridge to Shelton Road Bridge: This 5-mile-long reach varies between 18 and 105 feet wide. Depth varies from a 1-foot riffle to a 12-foot deep glide. A moderate gradient exists in this stretch. Gravel makes up most of the river substrate, with sand and cobble present to a lesser degree. There is limited vegetation cover due to the narrow and steep river channel characterized by large boulders and deep plunge pools that provide little available soil. As the canyon ends, the river widens, slope decreases and riffle features become more dominant. Overhanging vegetation and woody debris increases in this reach. This reach has suffered some historical gravel mining, and the floodplain is currently being mined near Jenny Lind. However, tailing piles created by mining operations are suitable for gravel augmentation projects. In addition, perched floodplain abounds in this reach providing additional habitat during high water events (J.D. Wickert. USFWS. pers comm August 2005).
- River miles 31 to 25, Shelton Road Bridge to Bellota Weir: This reach is 6 miles long and varies between 12 feet and 108 feet wide. The maximum depth throughout the reach is 10 feet. Most of the habitat is represented by glides with a minimum depth of 2.5 feet. The remaining habitat is riffles with a minimum depth of 1 foot. This reach has a moderate gradient and drops 42 feet between the 167 foot elevation and 125 foot elevation. Gravel and cobble dominate the substrate, with sand also contributing. There is minimal vegetation cover on this river reach.
- River miles 25 to 0: The Central Valley reach, downstream of Bellota Weir, primarily supports orchards with occasional fields of row crops adjacent to the stream channel. Patches of native riparian or non-native herbaceous and woody vegetation grow along the banks of the Calaveras River. Some sections along this reach have overgrown riparian vegetation; others have dense stands of Giant Reed (*Arondo donax*) or Himalayan blackberry (*Rubus discolor*) that choke the river bed and banks. Near its confluence with the San Joaquin River, the Calaveras is a narrow, managed, tidal-influenced canal bordered on both banks by Stockton subdivisions, the University of the Pacific campus, and private and public boating facilities (USFWS 1998).

[USFWS] US Fish and Wildlife Service. 1998. Central Valley Project Improvement Act Tributary Production Enhancement Report. Central Valley Fish and Wildlife Restoration Program Office, Sacramento. May.

Wikert, J.D. USFWS. Personal communication. August 2005. John_Wickert@fws.gov

Mormon Slough

There is no evaluation of rearing or spawning habitat in the channels downstream of Bellota Weir. Salmon redds downstream of Bellota Weir in Mormon Slough were dewatered indicating Mormon Slough, which goes dry, does not provide adequate spawning habitat.

In general, Mormon Slough, a flood control channel, has water temperatures too warm to sustain a cold-water fishery. It is sparsely vegetated or has riprapped or eroding streambanks. The levees of Mormon Slough and the Stockton Diverting Canal support sparse grassy or shrubby vegetation. Orchards or light industry comprise most of the land uses.

Temperature

Water temperature affects fish viability and health. Salmonid tolerance of wide temperature ranges and quick fluctuations in temperature is very low. Although local population needs may vary, optimal temperatures for salmon are well-documented. Egg mortality can begin at water temperatures exceeding 56 ˚F, and water temperatures more than 70 ˚F can cause 100% egg mortality. Other ideal ranges for juvenile rearing, emergence, spawning, and adult migration are listed in Table 3-7 (CALFED 1999).

Table 3-7. Ideal temperature ranges for *O. mykiss* and Chinook salmon

Collins, Dillon, S.P. Cramer and Associates. Dec 2002. Dillon.Collins@valleyair.org

Temperature data were collected by S.P. Cramer and Associates (Collins 2002 pers comm) from seven stations between New Hogan Dam and a quarter-mile upstream of the Main Street Bridge in Mormon Slough. Water temperatures become increasingly warm from the dam to the farthest downstream site (Table 3-8). Figure 3-2 depicts the daily average water temperature in the Calaveras River and Mormon Slough from January 2000 to February 2002.

Table 3-8. Average water temperature at seven sites on Calaveras River and Mormon Slough, 12 Apr 2000 to 25 Oct 2001

Figure 3-2. Daily average water temperature in the Calaveras River and Mormon Slough, Jan 2000 – Feb 2002

Riparian Vegetation

Plant communities in the Calaveras River watershed include grassland, brush land and chaparral, riparian and oak woodland, and coniferous forest.

Recent surveys of riparian zone vegetation documented oaks (*Quercus* spp.), willows (*Salix* spp.), and alders (*Alnus* spp.), with an understory of herbaceous plants such as scrub oak (*Quercus berberidifolia*), chamise (*Adenostoma fasciculatum*), foothill pines (*Pinus sabiniana*), poison oak (*Toxicodendron diversilobum*), elderberry (*Sambucus mexicanus*), and native grasses downstream of New Hogan Dam.

Downstream of Bellota Weir, Mormon Slough is sparsely vegetated with immature willows (*Salix* spp.), cattails (*Typha angustifolia*), cottonwoods (*Populus* spp.), immature valley oak (*Quercus lobata*), and an abundance of nonnative species. Fruit and walnut orchards line both sides of the slough (USFWS 1989b). Mormon Slough was further modified by the US Army Corps of Engineers in 1969 to convey additional floodwater around the City of Stockton and is currently maintained as a flood control channel. Mormon Slough has mostly degraded banks and irregular contours. Some short portions of the slough have been riprapped or had concrete slabs placed on the banks since initial construction (USACE 1989).

[USFWS] US Fish and Wildlife Service. 1989b. Planning aid letter: Calaveras River and Mormon Slough Flood Control Investigation. Sacramento. October

[USACE] US Army Corps of Engineers. 1989. Draft Environmental Assessment Calaveras River Reconnaisance Study for Flood Control. Sacramento District.

The Calaveras River channel downstream of the split with Mormon Slough contains little natural riparian vegetation (M. Hendrick 2005 pers obs). Few valley oaks (*Quercus lobata*) and cottonwoods (*Populus* spp.) are on this portion of the river channel. Many sections of the channel are overgrown with invasive plants. European blackberries (*Rubus discolor*) and *Arundo donax* choke sections of the channel. It is noted in the Calaveras River Watershed Management Plan (CCWD 2002) that the channel is moderately confined with overgrown vegetation. There are some areas along the Calaveras River that have orchards along the bank (M. Hendrick 2005 pers obs). As the Calaveras River channel passes through the City of Stockton, the vegetation is characterized by grasses and weeds with little to no riparian vegetation (M. Hendrick 2005 pers obs).

[CCWD] Calaveras County Water District. 2002. Calaveras River Watershed Management Plan. Phase I. San Andreas, CA.

Fluvial Geomorphology

The reach from New Hogan Dam to Cosgrove Creek is alluvial exhibiting alternate bar-pool morphology with encroaching vegetation in the channel (see Figure 2-3g.). Typical channel width is 85 feet (26 meters) and average channel gradient is about 0.005% (based on USGS 1:24,000 topographic maps). The bed is composed of gravel, cobble, and sand. Bedrock outcrops are found in the channel bed immediately downstream of New Hogan Dam. The channel bed surface contains large quantities of fine sediment (< 2 mm) (Stillwater Sciences 2000).

Stillwater Sciences. 2000. Calaveras River Spawning Gravel Assessment. Technical Memorandum for USFWS Anadromous Fish Restoration Program.

Stillwater Sciences (2000) evaluated spawning habitat at New Hogan Dam and for approximately 1.5 miles downstream. Encroachment of riparian vegetation and lack of any recruitment of new gravels appears to have reduced the quality of these spawning grounds. Detailed substrate conditions were assessed at five riffles in the study area. The study revealed few potentially suitable spawning riffles because of the relatively poor gravel quality and the presence of subsurface sands and fines. The report states that the habitat upstream of Bellota Weir would sustain viable *O. mykiss* and Chinook salmon populations (Stillwater Sciences 2000; CCWD 2002).

Downstream of Cosgrove Creek to 1.5 miles downstream of New Hogan Dam, the channel enters a steep, bedrock confined gorge with average channel gradient of 0.013. Riffles in the reach are composed of large boulders, and there are no gravel deposits suitable for spawning. Pools suitable for adult salmon holding are common in this reach (Stillwater Sciences 2000).

Mining is a part of the Calaveras River history. Historical placer and hard-rock mining has occurred along the lower Calaveras River from the confluence with Cosgrove Creek to the South Gulch area downstream of Jenny Lind. Many of the old workings and tailings piles have altered the course and flow of the river. In a few cases, the river has moved into an old work pit, forming a low-velocity pond within the active channel of the river (CCWD 2002).

Mormon Slough at the Stockton Diverting Canal is approximately 85-feet wide between the levees. The entire length of Mormon Slough flood control channel's substrate is riprap-sized rocks or bare earth. Gravel is limited. The many artificial structures control gradient throughout this channel. Sediment sources in this channel are from the banks or the mobile material of the channel bottom consisting of minor amounts of alluvium and native soils. The confluence of the Calaveras River and the Stockton Diverting Canal is a rectangular channel between levees. The confluence of the Calaveras River and the San Joaquin River is a trapezoidal channel, with abundant vegetation and riprap. The upstream extent of tidal influence occurs just downstream of the confluence of the Stockton Diverting Canal and the Calaveras River

Flood control reservoirs, water supply reservoirs, and gravel extraction have reduced coarse gravel recruitment and degraded spawning habitat within the Calaveras River watershed (FFC 2000).

[FFC] Fishery Foundation of California. 2000. Calaveras River Chinook salmon and Steelhead population abundance and limiting factors analysis – CalFed ERP Grant Proposal. P.O. Box 27114 Concord, California 94527

Water Quality

SEWD and Calaveras County Water District engaged Tetra Tech to conduct field assessments for water quality at 100 locations in the Calaveras River watershed (CCWD 2002). The selected locations included known and potential point and nonpoint pollution sources, habitat monitoring stations, and water quality monitoring locations.

Historical water quality data collected from surface waters in the Calaveras River watershed are maintained by the US Environmental Protection Agency in its STORET-LEGACY database. Water quality data are available for the years 1958 to 1987. The data correspond to monitoring performed by the California Department of Water Resources, US Geological Survey, and US Army Corps of Engineers. Data were collected by the three agencies from a total of about 30 sites within the watershed that include the Calaveras River upstream and downstream of New Hogan Lake, multiple locations and depths in New Hogan Lake, tributaries to the Calaveras River, the Stockton Diverting Canal, and Mormon Slough.

Single, non-averaged dissolved oxygen levels were measured at 12 locations throughout the watershed during different times of year between 1958 and 1959. These data indicate that DO levels were historically high enough to support cold-water fisheries and were above current minimum water quality standards. In comparison, limited data from the 1970s indicate that DO levels were decreasing in the lower Calaveras River watershed (CCWD 2002).

DO = dissolved oxygen

More recent water quality monitoring in the Calaveras River watershed primarily consists of raw and treated water monitoring conducted at the Sheep Ranch, Jenny Lind, and the SEWD Dr. Joe Waidhofer water treatment plants and intakes. The Sheep Ranch and Jenny Lind water treatment plants are operated by the Calaveras County Water District and supply drinking water to consumers in Calaveras County. Sheep Ranch water treatment plant is upstream of New Hogan Lake, and Jenny Lind water treatment plant is downstream. The SEWD water treatment plant is near the city of Stockton and supplies drinking water to consumers in the Stockton urban area of San Joaquin County (CCWD 2002).

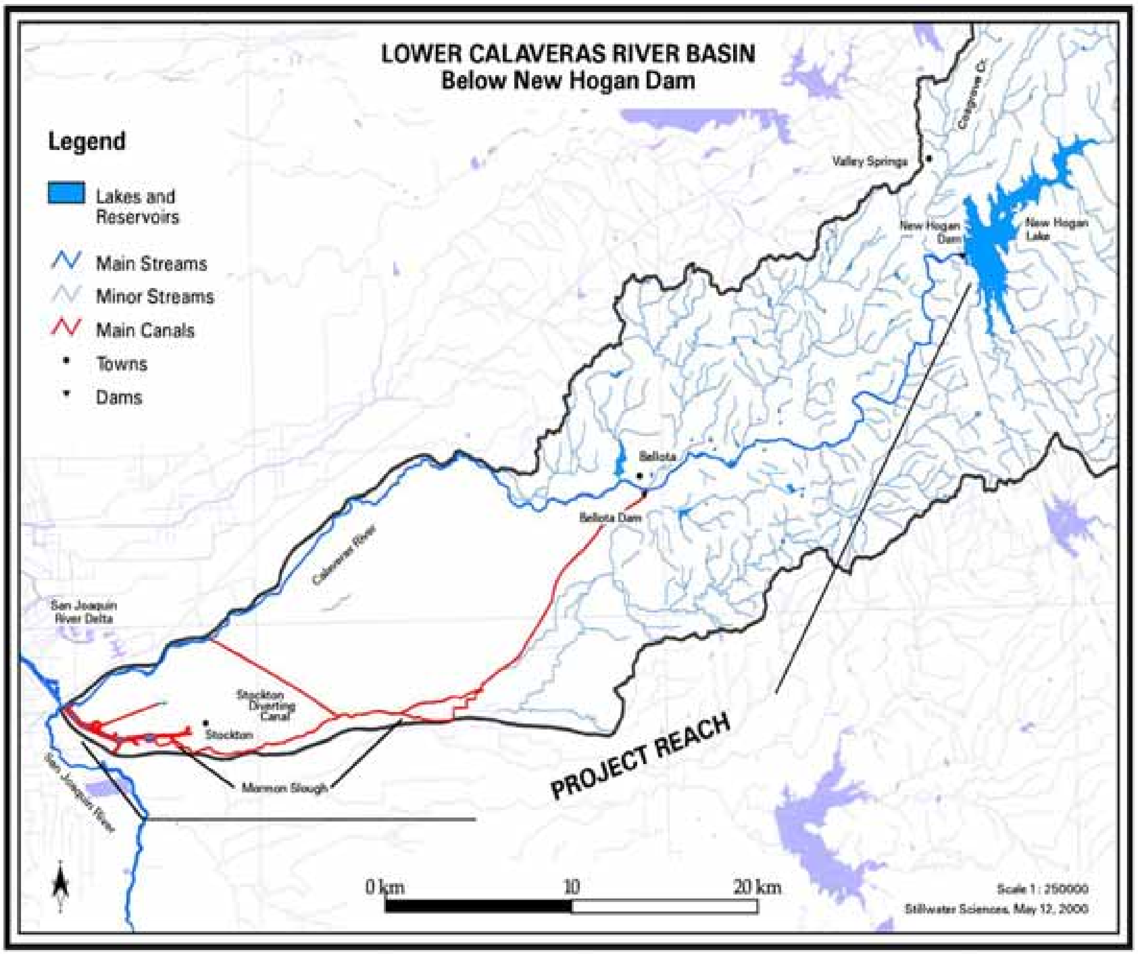
Results of the water quality assessments and impacts on cold water fisheries in the Calaveras River watershed are not conclusive at this time. Potential impacts in the lower watershed may be related to nutrient, bacteria, sediment loading, water management practices, and migration barriers. The anthropogenic sources of the potential water quality impacts include livestock grazing, residential ranchettes, septic system failure, point and nonpoint industrial discharge, golf course drainage, water diversions, flashboard dams, dewatering of the Calaveras River channel, and agricultural practices. Streambank erosion associated with Indian Creek, streambank undercutting and mass wasting along the Calaveras River, and historical gravel mining pits in the active channel may also impact water quality in the system (USACE 1989; CCWD 2002).

Chapter 3 Biological Conditions

List of Figures

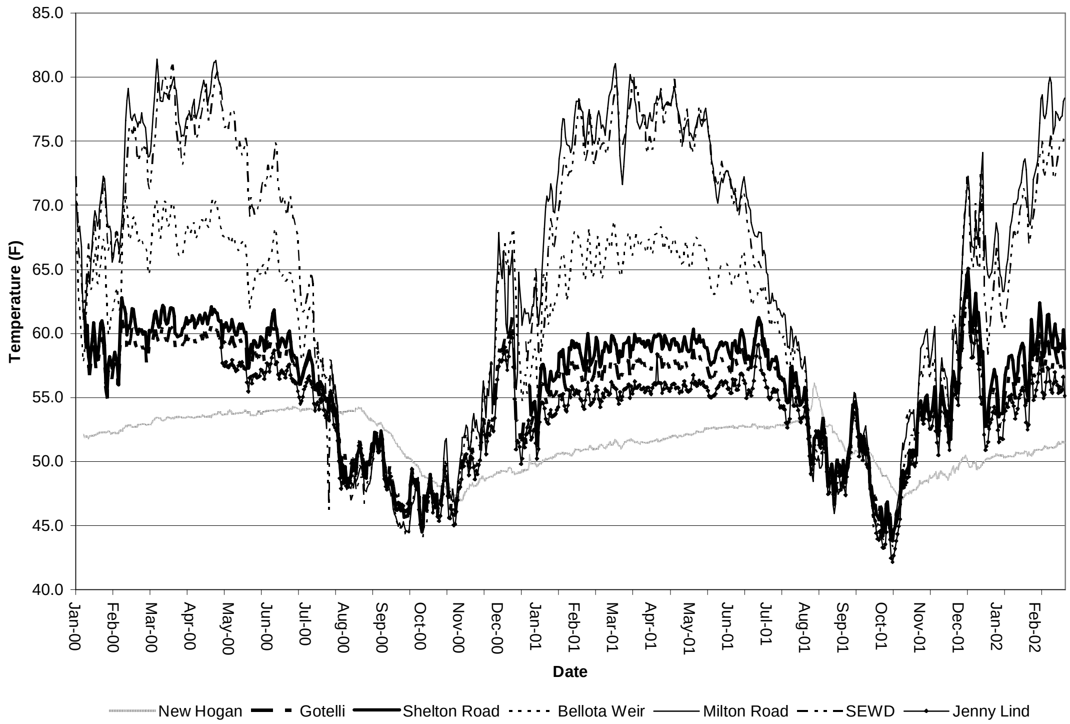
List of Tables

Figure 3-1. Lower Calaveras River basin



Source: Stillwater Sciences

Figure 3-2. Daily average water temperature in the Calaveras River and Mormon Slough, Jan 2000 to Feb 2002



Source: SP Cramer and Associates (2002)

Table 3-1. Expected migration periods for *O. mykiss* and fall-run Chinook salmon in the Calaveras River

	Adult migration period	Juvenile outmigration period
Fall-run Chinook salmon	Sept. – Dec.	Jan. - June
O. mykiss	Oct. – Mar.	Jan. - June

Table 3-2. Generalized life history timing of fall-run Chinook salmon in the San Joaquin River basin (Tuolumne River)

Migration period	Peak migration	Spawning period	Peak spawning	Juvenile emergence period	Juvenile stream residency
Oct. – early Jan.	November	Late Oct. – Jan.	November	Dec. – Apr.	1-5 months

Source: Moyle 2002.

Table 3-3. Life history timing of fall-run Chinook salmon and *O. mykiss* in the Mokelumne River

	Migration period	Peak migration	Spawning period	Peak spawning	Fry emigration	Smolt emigration
Fall-run Chinook salmon	Aug. – Jan.	Oct. – Nov.	Sep. – Jan.	Late Oct. – early Dec.	Dec. - May	Dec. – May
O. mykiss	Aug. – Mar.	Oct. – early Mar.	Nov. – Mar.	Dec. – Feb.	N/A	Dec. – May

Source: Williams and others 2003

Table 3-4. Fall 2001 and winter 2002 salmon migration survey results

Date	Location	Situation	Number	Flow recorded at Mormon Slough gage
11/20/01	Stockton Diverting Canal .25 mile between Budiselich Dam and Hwy 99	Stranded salmon, unspawned	6 live, 3 dead (2 female, 1 male)	0
11/21/01	Budiselich Dam	fish rescue, stranded fish moved above Bellota Weir	9 fish, two died prior to release. 3 new carcasses found.	0
11/26/01	Budiselich Dam	stranded	2 carcasses, ad-clipped	3
12/4/01	Mormon Slough, Caprini Crossing	stranded	1 live female, adipose intact	13
12/4/01	Budiselich Dam	stranded	1 dead male, adipose intact	13
12/6/01	Bellota Weir	stranded	1 dead male, adipose intact	1
12/19/02	Caprini Low Flow Road Crossing	wedged under riprap	1 dead salmonid; species unknown	50 cfs

cfs = cubic feet per second
Source: Fishery Foundation of California

Table 3-5. Fall 2003 and winter 2004 salmon migration survey results from Mormon Slough

Number	Date	Location	Latitude/ Longitude	Life stage	Fork length (mm)	Alive/ dead
1	11/15/03	Railroad crossing	N37 59.282 W121 15.870	Adult Male	890	Dead
2	11/15/03	50 yds upstream of railroad crossing	N37 59.267 W121 15.835	Adult Female	686	Dead
3	11/15/03	100 yds upstream of railroad crossing	N37 59.241 W121 15.760	Adult Female	825	Dead
4	11/15/03	100 yds upstream of railroad crossing	N37 59.241 W121 15.760	Adult Male	400	Dead
5	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Male	559	Alive
6	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Female	559	Alive
7	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Female	797	Alive
8	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Female	635	Alive
9	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Male	737	Alive
10	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Male	660	Alive
11	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Male	660	Alive
12	11/19/03	Hwy 99	N37 58.895 W121 14.935	Adult Male	864	Alive
13	11/19/03	Budiselich Dam	N37 59.282 W121 15.870	Adult Unk	508	Dead
14	11/19/03	Budiselich Dam	N37 59.267 W121 15.835	Adult Male	533	Dead
15	11/19/03	Budiselich Dam	N37 59.241 W121 15.760	Adult Male	686	Dead
16	11/19/03	Upstream of Fremont Ave	N37 58.383 W121 13.739	Adult Female	775	Dead
17	12/3/03	near tidewater	N37 59.601 W121 17.438	Adult Male	615	Dead
18	12/3/03	near tidewater	N37 59.601 W121 17.438	Adult Female	814	Dead

Table 3-5 continued on next page

Number	Date	Location	Latitude/ Longitude	Life stage	Fork length (mm)	Alive/ dead
19	12/3/03	West Ave	N37 59.595 W121 17.433	Adult Male	590	Dead
20	12/30/03	Caprini low-flow road crossing	N37 57.704 W121 09.582	Adult Male	Unk	Alive
21	12/30/03	Caprini low- flow road crossing	N37 57.704 W121 09.582	Adult Male	Unk	Alive
22	1/14/04	Bellota Weir	N38 03.082 W121 00.773	Adult Male	845	Alive
23	1/14/04	Downstream of flood road	N38 00.379 W121 04.247	Adult Male	~750	Alive
24	1/14/04	Bellota Weir	N38 03.082 W121 00.773	Adult Female	825	Dead
25	1/14/04	Caprini low-flow road crossing	N37 57.704 W121 09.582	Adult Female	835	Dead
26	2/9/04	Upstream of Jack Tone Road Bridge	N37 57.893 W121 08.594	Adult Female	680	Dead

Source: Fishery Foundation of California and USFWS-AFRP

Table 3-6. Fall 2003 and winter 2004 *O. mykiss* migration survey results from Mormon Slough

Number	Date	Species	Location	Latitude/ Longitude	Fork length (mm)	Alive/dead
1	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	209	Alive
2	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	250	Alive
3	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	188	Alive
4	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	200	Alive
5	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.689	177	Alive
6	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	148	Alive
7	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	161	Alive
8	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	170	Alive
9	11/5/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	176	Alive

Table 3-6 continued on next page

Number	Date	Species	Location	Latitude/ Longitude	Fork length (mm)	Alive/dead
10	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	234	Alive
11	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	175	Alive
12	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	164	Alive
13	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	165	Alive
14	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	144	Alive
15	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	179	Alive
18	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	160	Alive
19	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	185	Alive
20	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	160	Alive
21	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	167	Alive
22	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	160	Alive
23	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	168	Alive
24	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	169	Alive
25	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	153	Alive
26	11/8/03	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	175	Alive
27	1/14/04	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	145	Alive
28	1/14/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	195	Alive
29	1/14/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	185	Alive
30	1/14/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	210	Alive
31	1/14/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	190	Alive
32	1/14/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	125	Alive
33	1/22/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	210	Alive

Table 3-6 continued on next page

Number	Date	Species	Location	Latitude/ Longitude	Fork length (mm)	Alive/dead
34	1/22/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	222	Alive
35	1/22/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	210	Alive
36	1/22/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	199	Alive
37	1/22/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	210	Alive
38	1/22/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	179	Alive
39	1/22/04	*O. mykiss*	Budiselich Dam	N37 58.841 W121 14.823	200	Alive
40	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
41	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
42	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
43	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
44	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
45	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
46	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
47	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
48	1/22/04	*O. mykiss*	Wilson Way	N37 59.229 W121 15.736	Decayed	Dead
49	2/6/04	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685		Alive
50	2/6/04	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685		Alive
51	2/6/04	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685		Alive
52	3/19/04	*O. mykiss*	Budiselich	N37 58.835 W121 14.820	160	Alive
53	3/19/04	*O. mykiss*	Budiselich	N37 58.835 W121 14.821	135	Alive
54	3/19/04	Chinook	Budiselich	N37 58.835 W121 14.822	65	Alive
55	3/25/04	*O. mykiss*	Cherokee Ln	N37 59.147 W121 15.479	215	Alive

Table 3-6 continued on next page

Number	Date	Species	Location	Latitude/ Longitude	Fork length (mm)	Alive/dead
56	3/25/04	*O. mykiss*	Budiselich Dam	N37 58.835 W121 14.821	191	Alive
57	3/25/04	*O. mykiss*	Budiselich Dam	N37 58.835 W121 14.821	195	Alive
58	3/25/04	*O. mykiss*	Bellota Weir pool	N37 03.137 W121 00.685	161	Alive

Source: Fishery Foundation of California and USFWS - AFRP

Table 3-7. Ideal temperature ranges for *O. mykiss* and Chinook salmon

O. mykiss		**Chinook salmon**	
Life history stage	**Temperature range (˚F)**	**Life history stage**	**Temperature range (˚F)**
Adult migration	46-52	Adult migration[1]	< 70
Spawning	39-52	Spawning	< 56
Incubation and emergence	48-52	Incubation and emergence	< 56
Fry and juvenile rearing	45-60	Fry and juvenile rearing	< 60

Source: CALFED 1999
Hallock and others 1970

Table 3-8. Average water temperature at seven sites on Calaveras River and Mormon Slough, 12 April 2000 to 25 Oct 2001

Site	Temperature (ºC/ ºF)
New Hogan Dam	12.8/55.0
Jenny Lind Bridge	15.6/60.0
Gotelli Ranch	16.3/61.3
Shelton Road Bridge	17.1/62.8
Bellota Weir	21.6/70.9
Milton Road Bridge	27.5/81.5
Main Street Bridge	27.2/80.9

Source: Collins, Dillon (S.P. Cramer and Associates). Dec 2002. Personal communication

Chapter 4 Fish Passage Evaluation Methodology

Contents

Blank page for 2-sided printing

Chapter 4 Fish Passage Evaluation Methodology

California Department of Water Resources' staff from the Fish Passage Improvement Program evaluated fish passage at accessible structures on the Calaveras River system—Calaveras River, Mormon Slough, and Stockton Diverting Canal—in two phases.

In Phase I, we visited the structure sites, took notes on their biological and morphological conditions, and measured the dimensions of the physical features of the structures that affect fish passage. Based on these measurements, we scored the structures regarding their potential impediment to fish passage. This scoring helps to prioritize fish passage improvement projects in the river system.

In Phase II, we identified each structure as either not a barrier or as a type of barrier to fish passage. Knowing fish passage capabilities for a range of flows at a structure is necessary to identify the type of barrier the structure is according to California Department of Fish and Game (DFG) guidelines. Hydraulic modeling is often used to assess fish passage under a variety of flow conditions. Seventeen structures on the Calaveras River system were then selected for hydraulic modeling. The structures were selected for their representative nature of the different structures configurations encountered along the river system. Hydraulic modeling tells us what type of barrier a structure is, and where and when fish passage is impaired at the structure. This information is necessary for designing fish passage improvements at a structure.

DFG = California Department of Fish and Game

Fish passage is considered to be impaired if fish passage criteria are not met throughout the defined range of fish passage flows. We reviewed the most recent National Marine Fisheries Service (NMFS) and DFG fish passage publications to develop criteria for Phase I and II fish passage evaluations. The criteria available in those publications are presented below.

NMFS = National Marine Fisheries Service

Literature Review – Fish Passage Criteria

DFG and NMFS provide definitions of three barrier types to describe the potential for a structure to impede salmonid migration: temporal, partial, and total barriers. Table 4-1 provides definitions of the barrier types and their potential impacts on fish passage.

Table 4-1. Definitions of barrier types and their potential impacts

The criteria for determining the barrier type at a structure can be split into two categories: structural criteria and hydraulic criteria. Structural criteria are used as a first pass evaluation of fish passage to provide an estimate of what kind of barrier a structure is as defined in Table 4-1. The criteria are based on physical dimensions of a structure and not on hydraulics at and near the structure. Structural criteria include slope, width, or diameter of opening relative to the active channel width, outlet drop, elevation of the tailwater control relative to structure inlet, outlet, and pool invert, and whether the channel substrate is continuous over or through the structure (DFG 2003). Structure length can also be used as a structural criterion for first pass fish passage evaluations.

[DFG] California Department of Fish and Game. 2003. California Salmonid Stream Habitat Restoration Manual. Chapter IX. Sacramento. Apr.

Hydraulic criteria are used to determine the barrier type for a structure and what percentage of the migration period fish passage is impaired. Hydraulic criteria include flow depth, jump height, jump pool depth, and flow velocity. These criteria have been developed for anadromous fish based on their physical abilities.

[DFG] California Department of Fish and Game. 2002. Culvert Criteria for Fish Passage. The Resources Agency, Sacramento. 15p.

The size of a fish determines the minimum flow depth needed for unimpaired upstream and downstream movement. A fish needs enough water to swim, which is about half of the fish's body depth. DFG and NMFS criteria for depth are 1 foot for adult anadromous salmonids and 0.5 feet for juvenile salmonids (DFG 2002, NMFS 2001). The necessary flow depth for fish passage is higher over riprap because low flows tend to flow through the rock layer and also tend to be very turbulent. Highly turbulent flows disorient fish and act as a barrier just as a structure might. After consulting with DFG engineers, the minimum depth requirement for fish passage over riprap was doubled from normal depth requirements (George Heise, DFG, 2004 pers comm). Thus, for adult anadromous salmonids the minimum flow depth over riprap is 2 feet, and for juveniles the minimum flow depth over riprap is 1 foot. Table 4-2 summarizes the flow depth requirements for juvenile and adult anadromous salmonids.

[NMFS] National Marine Fisheries Service. 2001. Guidelines for Salmonid Passage at Stream Crossings. Final draft. Southwest Region. Sep.

Heise, George. California Department of Fish and Game. Personal communication, 2 Sep 2004. GHEISE@dfg.ca.gov.

Table 4-2. Minimum flow depths for adult and juvenile salmonid passage

Salmonids require a pool from which to initiate a leap over an obstacle. NMFS criteria for minimum water depth for jump pools is at least 1.5 times the jump height or a minimum of 2 feet deep, whichever is deeper (NMFS 2001). The plunge pool depth for downstream migrating juveniles should be at least 1.5 times the fall height over a barrier and a minimum of 2 feet deep to avoid fish injury (George Heise, DFG, Apr 2007 pers comm). These criteria are summarized in Table 4-3.

Heise, George, California Department of Fish and Game. Personal communication, Apr 2007 GHEISE@dfg.ca.gov

Table 4-3. Minimum jump and plunge pool depths for adult and juvenile salmonid passage

Flow velocity criteria have been developed based on the swimming abilities of adult anadromous salmonids. Swimming performance studies for anadromous salmonids have determined the length of time that specific species of salmonids can maintain a certain swimming mode. Burst swimming mode is a faster speed sustained over a shorter time period, such as when a fish is avoiding a predator or for passage through difficult areas. Prolonged swimming mode is a slower speed sustained over a longer period of time, such as when fish are migrating. The results of the swimming performance studies are summarized in Table 4-4.

Table 4-4. Swimming and leaping abilities for juvenile and adult anadromous salmonids

fps = feet per second

Anadromous fish swimming performance has been used in design criteria for maximum water velocity through culverts of various lengths. These criteria can also be used for other structure types that are potential barriers to fish passage. Flow velocities increase through culverts because they have smooth surfaces, constrict flow width, and alter the bed slope of the stream. Other barrier types have similar characteristics that cause increased flow velocities. In general, the longer the culvert, chute, or concrete or riprap section of channel, the lower the velocity needs to be so that fish do not exhaust themselves before they can swim completely through. For fish passage improvement structure retrofit or removal designs, the maximum velocity through a culvert or over a structure is recommended at 6 feet per second for a structure less than 60 feet long (George Heise, DFG, Feb 2007 pers comm). However, for fish passage evaluation purposes, structures less than 60 feet long may be allowed velocities in excess of 6 fps based on burst swimming mode speeds. Table 4-5 presents allowable maximum velocities based on

Heise, George, California Department of Fish and Game. Personal communication, Feb 2007 GHEISE@dfg.ca.gov

Table 4-5. Allowable maximum velocities vs. structure length for adult salmonids

structure length (USDOT 1990, Behlke and others 1991, NMFS 2001, DFG 2002).

The structure length (derived from adding the length of the structure to the estimated length of the riprap) was used to select the corresponding maximum velocity (see Table 4-5). The length of riprap is estimated from the water surface profile output of the hydraulic model and is measured from the downstream end of the structure to the point on the profile at which the depth of flow on the riprap is 2 feet (Figure 4-1). At a relatively low flow (Q_1), water cascades over the riprap until it reaches a depth of 2 feet, a distance of y_1 from the structure. The structure length (x) and the riprap length (y_1) are added together to obtain the total structure length. This structure length is then read in Table 4-5, and the corresponding maximum allowable velocity is determined. As the flow increases to Q_2, the effective length of the riprap decreases as 2 feet in depth is reached closer to the structure at distance y_2. Once again, to get the total structure length, the riprap and physical structure length are summed. This implies that as the flow and depth across the structure and riprap increase, maximum allowable velocity will also increase.

[USDOT] US Department of Transportation, Federal Highway Administration. 1990. Fish Passage through Culverts. Report No. FHWA-FL-90-006. Washington DC. Nov.

Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991. Fundamentals of Culvert Design for Passage of Weak-Swimming Fish, Final Report. Alaska DOT&PF and USDOT, Federal Highway Administration. FHWA-AK-RD-90-10.

Figure 4-1. Measuring structure length over riprap

Anadromous salmonids typically migrate upstream during higher flows triggered by hydrologic events such as rainstorms or snowmelt runoff. Conversely, during low flow periods on many smaller streams, water depths within the channel can become impassable for both adults and juvenile salmonids. DFG (2002) and NMFS (2001) have defined upper and lower flow limits specifically for streams within California in order to identify the range of flows that road crossings should accommodate for fish passage (Table 4-6). Typically, the high design flow is used to determine the maximum water velocity within a culvert, and the low design flow is used to determine the minimum depth of water within a culvert (DFG 2002 and NMFS 2001). Between the lower and upper passage flows, road crossings should allow unimpeded passage of all adult salmonids. These upper and lower passage limits also apply to other structure types that potentially impair fish passage. When evaluating passage at different structure types, flow velocities and depths should be checked against criteria throughout the flow range.

Table 4-6. Upper and lower fish passage flows for stream crossings

The upper and lower fish passage flows listed in Table 4-6 are defined as exceedance flows. The exceedance percentage is the amount of time that the specified flow is exceeded. As an example, a 1% flow was only exceeded 1% of the time in the historical record. Exceedance flows that are the upper and lower fish passage flows for adult salmon and *O. mykiss* and for juvenile salmonids are determined from flow duration curves. These curves are developed using the historical daily (mean) flow values from a streamflow gage. The data are ordered from highest to lowest flow and then each flow value is given a percentage defined as the number of daily flows that are greater based on the total number of days. The flow duration curve is obtained by plotting flow versus the percentage of time that flow is equaled or exceeded. The upper and lower passage flows are read directly from the flow duration curve.

After fish passage evaluation is complete, it is common to develop solutions to fish passage at problem structures. When considering fish passage at road crossings, and in particular culverts, NMFS (2001) recommends that the following structure solutions be considered in order of preference:

1 No crossing – road realignment to avoid crossing the stream
2 Bridge – spanning the stream to allow for long-term dynamic channel stability
3 Streambed simulation strategies – bottomless arch, embedded culvert design, or ford
4 Non-embedded culvert – often referred to as a hydraulic design, associated with more traditional culvert design approaches limited to low slopes for fish passage
5 Baffled culvert, or structure designed with a fishway – for steeper slopes

Because other structure types impair fish passage in ways similar to culverts, the recommendations for culverts can be extended to other structure types that impair fish passage. If possible, a structure that impairs fish passage should be removed. If removing the structure is not possible, the next most desirable solution is one that allows the natural movement of bedload and formation of a stable bed across the structure. The next most preferable solution is one where the structure is designed to meet all of the hydraulic criteria for fish passage. The least preferable solution to fish passage at a structure is a retrofit such as a fish ladder to allow passage.

Phase I Fish Passage Evaluation Methodology

In Phase I of fish passage evaluation, we visited 97 of the 100 known structure sites[1], took notes on their biological and morphological conditions, and measured the dimensions of the physical features of the structures that affect fish passage. Based on these measurements, we scored the structures regarding their potential impediment to fish passage. This scoring helps to prioritize fish passage improvement projects in the river system. The biological, morphological, and physical conditions at each structure are described in the site descriptions in Appendix A.

Appendix A Site Descriptions

The Calaveras River system has six main types of structures:

- Flashboard dam bases (boards removed)
- Low-flow road crossings without culverts
- Permanent dams and weirs
- Road and low-flow road crossings with culverts
- Seasonal flashboard dams (boards in place)
- Vehicle, pedestrian, and railroad bridges

Other unique structures on the Calaveras River system were not scored. These consist of log jams and remnant structures. Rather than score these structures, we recommend their removal.

We used the structural criteria identified in the previous section to evaluate fish passage in Phase I. These criteria include structure length, ratio of structure width to channel width, outlet drop, slope, elevation of the tailwater control relative to structure inlet, outlet, and pool invert, and whether the

[1] DWR did not receive permission to access two of the known structure sites.

channel substrate is continuous over or through the structure. We did not use slope and elevation of the tailwater control relative to structure inlet, outlet, and pool invert in our evaluations. Slope was not used because it applies only to culverts. Other structures, such as bridges with aprons, low flow crossings without culverts, and seasonal flashboard dams tend to have flat slopes that could lead to better evaluations of fish passage than those for culverts, when that may not be the case. The elevation of the tailwater control points was not measured because some structure evaluations occurred during irrigation season when access and safety became an issue. It is difficult to locate tailwater control when the channel is backwatered from seasonal flashboard dams. We used the remaining structural criteria to evaluate and score the structures. Appendix B includes the data sheets used for scoring each type of structure found in the Calaveras River system.

Appendix B Data Sheets for Scoring

Structure length was measured at each structure. Flow velocities are often higher over and through structures, causing fish to swim in burst mode in order to pass the structure. However, if the structure is too long, fish may become exhausted before they swim completely past the structure and may be swept downstream. At bridges, structure length was defined as the sum of the apron length and the riprap length along the channel. At culverts, structure length was defined as the sum of the longest culvert length and the apron and riprap lengths. The structure length at low flow crossings was defined as the distance between the upstream and downstream edges of the crossing plus the riprap length. The structure length at flashboard dam bases was defined as the distance between the upstream and downstream edges of the dam base plus the riprap length.

The structure width (or span) and the channel width were measured at each structure. When a structure narrows the flow path of the water, flow velocities can increase and become too high for fish to swim past. If the width of the structure is less than the channel width, then the flow path is narrowed and velocity is increased and may exceed the swimming abilities of the fish. At bridges, the width between bridge abutments was recorded and compared to channel width. At culverts, the diameters of the pipes were measured and compared to channel width. At low flow crossings without culverts and at permanent dams and weirs, the crest length between the channel banks was measured and compared to channel width. At flashboard dam bases, the width of the opening between abutments was measured and compared with channel width.

Outlet drop or drop across the structure was measured at each structure. The drop dimension provides a conservative measure of the structure’s total maximum height. This measurement equates to the potential maximum vertical jump or fall distance that migrating fish may encounter. At bridges, drop was measured when either an apron or riprap was present. It was measured from the downstream end of the apron or riprap to the channel bottom. At culverts, drop was measured from the invert of the outlet of the lowest pipe to the channel bottom. At low flow crossings without culverts, drop was measured from the downstream edge of the structure to the channel bottom. At permanent dams and weirs, drop was measured from the crest to the channel bottom. At flashboard dam bases, drop was measured from the downstream edge of the structure to the channel bottom.

We gave special consideration to the continuous channel substrate criterion for Phase I evaluations. Instead of only recording whether the channel substrate was continuous through the structure, we noted if there was riprap or an apron present across the width of the channel interrupting the channel substrate. We considered riprap and apron separately because they have different effects on the flow. Although both tend to spread flow rather than concentrate it into a low flow path, aprons cause water to flow in a thin sheet at high velocity, and riprap allows water to flow down within the rock causing shallow flow depths. Riprap also increases turbulence that can disorient fish.

Each criterion was evaluated using a point system. Because of the wide range of structure lengths measured as well as the significant effect length has on fish swimming speed, structure length can be assigned a maximum score of 2 points. The allowable velocity at a structure becomes quite slow when the structure is longer than 60 feet. Thus, a structure receives 2 points if it has a length greater than 60 feet. The allowable velocity is very rapid when structure length is less than 30 feet, so a structure receives 1 point if it is between 30 and 60 feet long. Width has a less defined impact on fish swimming capabilities than length. Thus, structure width versus channel width is only assigned 1 point. If structure width is less than channel width, then the structure receives 1 point. Drop has a significant impact on fish passage and is counted for a maximum of 2 points. Two feet is the drop criteria used for culvert evaluations by DFG (2003). Design criteria call for drops of 1 foot or less (DFG 2002 and NMFS 2001). Thus, if a drop is greater than 2 feet, the structure is assigned 2 points; if the drop is between 1 and 2 feet, the structure receives 1 point. The effects of riprap and aprons on fish passage are described above. If the structure has an apron, it is assigned 1 point. If there is riprap at the structure, the structure receives 1 point. Table 4-7 summarizes the point system used for evaluating fish passage and scoring structures.

Table 4-7. Phase I fish passage evaluation point system

Seasonal flashboard dams are only in place during juvenile migration season. Thus, they should not be compared with the other structure types when evaluating fish passage and scoring structures for adult salmonids. Instead, they should be evaluated separately and compared only to one another. Flashboards are installed at the dams in the beginning of the irrigation season, typically mid-April. They are removed in mid-October. Therefore, the seasonal dams do not affect most of the adult salmonid migration period, mid-October through March. Although early migrants may be in the San Joaquin River in early October, water deliveries in the Calaveras system are controlled so that water reaches only as far downstream as the farthest downstream diverter. Therefore, there is usually no flow connection between the Calaveras River or Mormon Slough and the San Joaquin River during irrigation season.

Flashboard dams can affect juvenile salmonids migrating down the river from mid-April through June. Waterflow is relatively constant during the irrigation season. Therefore, water surface levels do not vary significantly, as they do during the rainy season. Hydraulic modeling of a wide range of flows is not required to determine if the structure is a barrier to fish passage.

Measurement of the dimensions below, during the irrigation season, can indicate if the structure is a barrier to fish passage.

To prioritize flashboard dams, we measure:

- Drop from crest to pool
- Depth of plunge pool
- Exposed riprap or apron

The drop describes the fall a juvenile salmonid could experience at each structure. In addition to the distance of the fall, we measure plunge pool depth and determine if there is a concrete apron or riprap below the drop. The points assigned to each criterion are shown in Table 4-8.

Table 4-8. Phase I fish passage evaluation at seasonal flashboard dams

Phase II Fish Passage Evaluation Methodology

In the first phase of fish passage evaluations, structures were compared and scored regarding their potential barrier to fish passage. The purpose of Phase II was to assess the extent of fish passage impairment at the structures on the Calaveras River system. In Phase II, we determined the flows when fish passage is impaired for the structures selected for modeling. The modeling also tells us where passage is impaired, that is, over the riprap, through the culverts, or over the dam base. Fish passage solutions can be developed based on this information.

In Phase II, we evaluated upstream passage for adult salmonids. Upstream passage was evaluated because the spawning habitat for adult Chinook and *O. mykiss* exists in the river reach just downstream of New Hogan Dam. Thus, adult salmonids must swim past many of the structures in order to spawn. In Phase II, downstream passage was evaluated for juvenile salmonids. Downstream passage was evaluated because the proposed preliminary design for Bellota Weir (CH2MHill 2005) allows for downstream juvenile passage to occur only when Bellota Weir is operated to release peak floodflows during storm events. At other times, juvenile salmonids would be contained upstream of Bellota Weir. Juveniles are contained upstream because water temperature is too warm downstream of Bellota Weir during irrigation season.

CH2MHill. 2005. Calaveras River Anadromous Fish Protection Project. Prepared for Stockton East Water District and Calaveras County Water District. Redding, CA. Apr.

The first step in Phase II evaluation was to group the structures on the Calaveras River system. We grouped the scored structures by structure type and river reach so that we could pick a representative structure for computer modeling. To select a representative structure to model, we reviewed photos, sketches, and field notes to verify that structures were scored correctly and to identify the structure that impacts fish passage most within the group. Because of the differences in channel geometry and flow conveyance between the Calaveras River and Mormon Slough, a typical structure represents similar structures only on the same reach of the river. The exact flows under which a represented structure is impaired will differ from the modeled structure that represents that group. However, the representative structure and the rest of the structures in the group are likely the same type of barrier: partial, temporal, total, or not a barrier (see Table 4-1). In general, the types of solutions we recommend for the modeled structures can also be applied to the other structures in that group.

The second step of Phase II evaluations was to model the representative structures from the groups. Hydraulic modeling simulates flow and determines water surface profiles in a river. With relatively few field measurements, modeling allows us to estimate depths and velocities in the river for a wide range of flows. The computer software we used to do the modeling was Hydrologic Engineering Centers River Analysis System (HEC-RAS). In order to create the models, we conducted detailed topographic surveys at each structure. With DWR's San Joaquin District staff, we surveyed cross sections upstream and downstream of the structures in addition to measuring the dimensions of the structures. We then developed a HEC-RAS model for each of the representative structures using the surveyed cross sections. To calibrate the models, water surface elevations and flow measurements were made at each of the structures in the winter of 2004 when runoff and flood releases occurred. The flow and water surface elevation measurements were used to adjust the HEC-RAS models so that they represent, or simulate, better the hydraulic conditions at their respective site locations.

HEC-RAS is hydraulic modeling software developed by the US Army Corps of Engineers Hydraulic Engineering Center. The software allows rapid one-dimensional steady and unsteady flow calculations.

We applied the hydraulic criteria for evaluating fish passage identified earlier in this chapter to the HEC-RAS model results to determine if structures are barriers to fish passage. These criteria include minimum flow depths and the modified minimum flow depths over riprap for juveniles and adults. Velocity criteria were also used. The velocity criteria at the structures include adding the length of riprap to the structure length to select the maximum allowable velocity over the structures. These criteria were used to determine if the structures are barriers to fish passage and if so, what type of barriers they are. To determine a structure's barrier type, it needs to be modeled under the proper flow range. The guidelines for lower and upper passage flows (see Table 4-6) were used to assess fish passage at the structures selected for modeling on the Calaveras River system. Current and historical mean daily flow records were used to perform flow duration analyses that determine the lower and upper passage flows on the distinct reaches in the Calaveras River system. At each structure, upper and lower passage flow limits were determined using DFG criteria for three migration periods: adult Chinook, adult *O. mykiss*, and juvenile salmonids. Flows below, within, and above these limits were modeled in HEC-RAS. We calculated the percent of the migration period that adult Chinook and *O. mykiss* and juvenile salmonids have unimpaired passage at each structure in order to determine the type of barrier. The flow duration analysis is summarized below. The details of the analysis and the passage flow ranges are given in Appendix C of this report.

Appendix C Details of Flow Duration Analyses

At some structures, the percent of time the structure has unimpaired passage may be very low. Therefore, in addition to calculating the percent of time for unimpaired passage, we also determined the number of migration seasons in the available flow data that fish have an opportunity for unimpaired passage. An opportunity for unimpaired passage means that at least one mean daily flow during the migration period is within the range of flows when fish have unimpaired passage at the structure.

Flow Duration Analysis

Flow duration analyses were performed to determine the lower and upper passage flows in the Calaveras River system for adult Chinook, adult *O. mykiss*, and juvenile salmonid migration periods. Flow data from gaging stations were used to develop flow duration curves that depict the system's current flow characteristics. The flow duration curves identify flow ranges on the system. Because no flow data exist on the Calaveras River downstream of the Stockton Diverting Canal, this analysis was not performed on this reach.

In this analysis, the Calaveras River system was divided into the following reaches:

- Calaveras River—New Hogan Dam downstream to Bellota Weir and Calaveras Headworks
- Calaveras River—Calaveras Headworks downstream to Stockton Diverting Canal
- Mormon Slough—upstream of Mormon Slough Railroad Crossing
- Mormon Slough—downstream of Mormon Slough Railroad Crossing
- Stockton Diverting Canal

The Calaveras River system was divided to account for the existence of gages and to show the impact of flow attenuation, seepage losses, irrigation pumping, and tributary inflows. In some cases, the limited number of gages on the system did not allow a precise accounting of the inflows and losses in a channel reach. However, much of the disparity lies in the lowest flows, and because of minimum DFG flow guidelines, many of these flows likely will not be used because most are zero. Zero flow within the migration period indicates that fish passage solutions at structures alone cannot provide passage throughout the entire migration period. Flow must be in the river in order for fish to be able to migrate. In general, available flow data on the system provide a good measure of the flow characteristics in each reach.

The flow duration curves were developed following DFG's California Salmonid Stream Habitat Restoration Manual, Chapter IX (2003). These curves were used for determining salmonid passage on the Calaveras River system for adult salmon, adult *O. mykiss*, and juvenile anadromous salmonids. Adult Chinook migration occurs during the months of September through December, adult *O. mykiss* migration occurs from October through March, and juvenile anadromous salmonids migrate from January through June (see Table 3-1).

Flow data for this analysis are derived from several gages that have been operated since 1965. Data from the 1965 to 2005 water years were used to represent post-New Hogan Dam flow conditions. Flow data prior to the completion of New Hogan Dam (initial storage operation began in late 1964) were not used in this analysis because they do not reflect current flow patterns in the system. Table 4-9 shows the gages and the period of record evaluated for this analysis.

Table 4-9. Gages on the Calaveras River system

The flow duration curves were developed using the daily (mean) flow values for each gage. The data were ordered from highest to lowest flow, and then each flow value was given a percentage defined as the number of daily flows that were greater based on the total number of days. The flow duration curve was obtained by plotting flow versus the percentage of time flow that is equaled or exceeded. The upper and lower fish passage flows for adult salmon and *O. mykiss* and for juvenile salmonids were determined from the flow duration curves. Adult salmon and *O. mykiss* upper passage flows were the 1% exceedence flows for their migration seasons. Their lower passage flows were the 50% exceedence flows for their migration seasons. In some reaches, the DFG minimum flow of 3 cubic feet per second was used because the 50% exceedence flow was less than 3 cfs. Because adult salmon and *O. mykiss* have different migration seasons, they will have different passage flow ranges. Juvenile salmon and *O. mykiss* have the same migration season, so one flow range was defined for all juvenile salmonids. The upper passage flow for juvenile salmonids is the 10% exceedence flow, and the lower passage flow for juvenile salmonids is the 95% exceedence flow. In some reaches, the DFG minimum flow of 1 cfs was used because the 95% exceedence flow was less than 1 cfs. A summary of these flows for each of the five reaches in the Calaveras River system is shown in Table 4-10. Detailed descriptions of the flow duration analyses for each reach are in Appendix C. The flow duration curves for each reach for each species and lifestage are also included in the appendix.

cfs = cubic feet per second

Table 4-10. Fish Passage flow limits in the Calaveras River system

Chapter 4 Fish Passage Evaluation Methodology

List of Figure and Tables

Figure 4-1. Measuring structure length over riprap

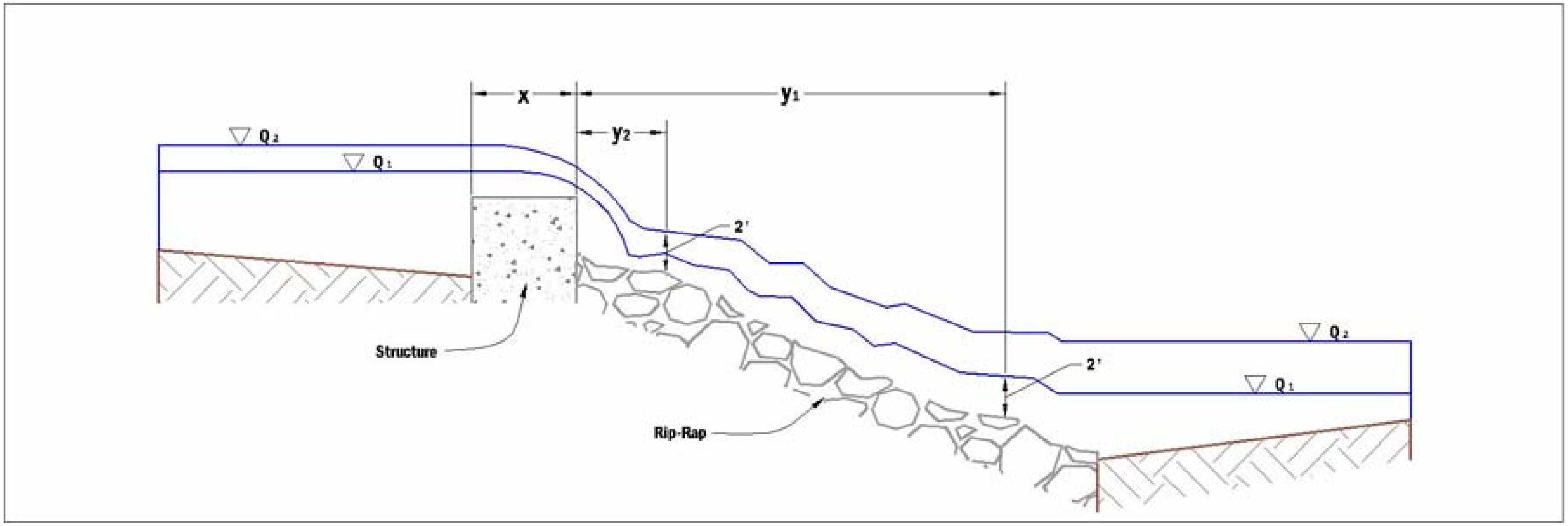


Table 4-1. Definitions of barrier types and their potential impacts

Barrier type	Definition	Potential impacts
Temporal	Impassable to all fish based on run timing and flow conditions	Delay in movement beyond the barrier for some period of time
Partial	Impassable to some fish at all times	Exclusion of certain species and life stages from portions of a watershed
Total	Impassable to all fish at all times	Exclusion of all species from portions of a watershed

Source: DFG 2003, Ch IX; adapted from Robison and others 2000

Table 4-2. Minimum flow depths for adult and juvenile salmonid passage

Species or lifestage	Minimum flow depth	Minimum flow depth over riprap
Adult Chinook, Coho, and *O. mykiss*	1.0 feet	2.0 feet
Juvenile Chinook, Coho, and *O. mykiss*	0.5 feet	1.0 feet

Adapted from NMFS 2001; DFG 2003; Heise 2004 pers comm

Table 4-3. Minimum jump and plunge pool depths for adult and juvenile salmonid passage

Species or lifestage	Jump pool depth	Plunge pool depth
Adult Chinook, Coho, and *O. mykiss*	1.5 times jump height or min. 2 feet deep	No criteria
Juvenile Chinook, Coho, and *O. mykiss*	No criteria	1.5 time the fall height or min. 2 feet deep

Adapted from NMFS 2000 and 2001; DFG 2003, Ch IX; Heise Apr 2007 pers comm

Table 4-4. Swimming and leaping abilities for juvenile and adult anadromous salmonids

Species or lifestage	Prolonged swimming mode		Burst swimming mode		
	Max swim speed	Time to exhaustion	Max swim speed	Time to exhaustion	Max leap speed
Adult Chinook, coho, *O. mykiss*	6.0 fps	30 min	10.0 fps	5.0 sec	12 fps
Juvenile coho salmon and *O. mykiss*	2.0 fps	30 min	3.0 fps	5.0 sec	3 fps

Note: fps = feet per second
Swim speeds adapted from NMFS (2000) and Hunter and Mayor (1986)

Table 4-5. Allowable maximum velocities vs. structure length for adult salmonids

Structure length (ft)	Adult anadromous salmonids (fps)
< 20**	10
20-40**	8
40-60**	6
60-100	5
100-200	4
200-300	3
> 300	2

Note: ft = feet; fps = feet per second
**This information was interpolated from the "Alaska Curve" (USDOT 1990, Behlke and others 1991)

Table 4-6. Upper and lower fish passage flows for stream crossings

Species/lifestage	Upper passage flow	Lower passage flow	
	Exceedence flow during migration	Exceedence flow during migration	Alternate minimum flow (cfs)
Adult salmonids; anadromous	1% (DFG & NMFS)	50% (DFG & NMFS)	3 (DFG & NMFS)
Juvenile salmonids	10% (DFG & NMFS)	95% (DFG & NMFS)	1 (DFG & NMFS)

Note: cfs = cubic feet per second
Source: DFG 2002; NMFS 2001

Table 4-7. Phase I fish passage evaluation point system

Dimension	Total length	Width	Drop	Apron	Riprap
0 Point	< 30 ft	structure width > channel width	< 1 ft	None	None or scattered
1 Point	30-60 ft	structure width < channel width*	1-2	Present	Across channel bottom
2 Points	> 60 ft	N/A	> 2 ft	N/A	N/A

* When structure constricts channel.

Table 4-8. Phase I fish passage evaluation at seasonal flashboard dams

Dimension	Crest to pool drop	Plunge pool depth	Exposed riprap or apron
0 Point	< 0.5 feet	≥ 1.5 x drop height and ≥ 3 feet	No
1 Point	0.5 – 1 feet	≥ 1.5 x drop height and 2 - 3 feet	N/A
2 Points	1 – 3 feet	< 1.5 x drop and 2 - 3 feet	N/A
3 Points	> 3 feet	< 2 feet	Yes

Table 4-9. Gages on the Calaveras River system

	Period of record	Evaluated period of record	Station ID	Data source
New Hogan Dam	1964-present	Oct 1990-Feb 2005	NHG*	USACE
Cosgrove Creek near Valley Springs	1929-1969, 1990-present	Oct 1990-Feb 2005	11309000	USGS, USACE
Calaveras River near Stockton	1925-1987	Jan 1965-Feb 1987	B02520	DWR
Mormon Slough at Bellota Weir	1948-1975, 1988-present	Oct 1964-Apr 1975, Oct 1995-Feb 2005	B02560, MRS*	DWR, USACE
Stockton Diverting Canal at Stockton	1944-1982	Oct 1964-Sept 1982	B02580	DWR

Note: USACE = US Army Corps of Engineers; USGS = US Geological Survey;
DWR = California Department of Water Resources
* Acronym used by DWR's California Data Exchange Center

Table 4-10. Fish passage flow limits in the Calaveras River system

Reach	Passage flow limit	Adult salmon	Adult *O. mykiss*	Juvenile salmonids
Calaveras River (New Hogan Dam downstream to Bellota Weir)	Lower	72 cfs	60 cfs	4 cfs
	Upper	1,426 cfs	3,989 cfs	384 cfs
Calaveras River (Calaveras Headworks downstream to Stockton Diverting Canal)	Lower	3 cfs*	3 cfs*	1 cfs*
	Upper	97 cfs	166 cfs	38 cfs
Mormon Slough, (upstream of Mormon Slough Railroad Crossing)	Lower	15 cfs	19 cfs	1 cfs*
	Upper	1,590 cfs	5,460 cfs	1,248 cfs
Mormon Slough, (downstream of Mormon Slough Railroad Crossing)	Lower	3 cfs*	6 cfs	1 cfs*
	Upper	978 cfs	4,540 cfs	847 cfs
Stockton Diverting Canal	Lower	3 cfs*	6 cfs	1 cfs*
	Upper	978 cfs	4540 cfs	847 cfs

* Minimum lower passage flow value from DFG guidelines is used.

Chapter 5 Fish Passage Evaluations Results

Contents

Blank page for 2-sided printing

Chapter 5 Fish Passage Evaluation Results

Results of Phase I and Phase II of Fish Passage Evaluations for artificial structures in the Calaveras River system are presented below. Phase I evaluations score the structures according to the point system described in Chapter 4. Phase II evaluations group the structures based on structure type and river branch. Representative structures were selected from the groups and modeled in Hydrologic Engineering Centers River Analysis System (HEC-RAS). The model results were analyzed to determine the percent of time fish can pass unimpaired and to identify the structures as non-barriers or as partial, temporal, or total barriers.

HEC-RAS is hydraulic modeling software developed by the US Army Corps of Engineers Hydraulic Engineering Center. The software allows rapid one-dimensional steady and unsteady flow calculations.

Phase I Fish Passage Evaluation Results

We evaluated bridges, low flow road crossings with culverts, low flow road crossings without culverts, permanent dams and weirs, and flashboard dam bases for fish passage and scored them regarding their potential barrier to fish passage. The results from the scoring are shown in Table 5-1. The possible scores range from 0 to 7 with 7 indicating the greatest potential to impair fish passage. Two of the structures in Table 5-1 have no score due to lack of landowner-approved access. The scoring breakdown is shown in Table 4-7 and described in Chapter 4.

Table 5-1. Structure scoring

As shown in Table 5-1, Clements Road Flashboard Dam was the only structure to score 7 points. The structure is made up of two concrete box culverts that have a significantly smaller width than the channel upstream of the structure. Flashboards can be installed at the inlet to the culverts for irrigation diversion. The culverts are 25 feet long and have a 5-foot long apron at their outlet. The apron is at the same elevation as the culvert outlet. There is a 3-foot drop from the downstream end of the apron to the riprap. The riprap is 36 feet long making the total structure length 66 feet. Thus, the structure scores a total of 7 points, which is the sum of 1 point for its width, 2 points for its length, 2 points for its drop, 1 point for an apron, and 1 point for riprap.

Numerous structures in Table 5-1 have a score of zero (0). These are normally bridges that do not narrow the flow with abutments and do not have aprons or riprap. Without aprons or riprap, a bridge has no structure length and no drop. Therefore, these bridges receive 0 points for length, width, drop, apron, and riprap. A score of 0 does not guarantee 100% passage at the structure. It only indicates that the structure has similar passage performance to normal channel cross sections. There must always be enough flow in the river to provide 1 foot of water depth in normal channel cross sections in order for a structure with 0 points to have 100 % passage.

As an additional example, the Calaveras Headworks received a score of 5 points. The Headworks controls the flow of water into the Calaveras River channel where the river splits into Mormon Slough and the Calaveras River. It is a tall earthen dam across the channel that provides conveyance through four box culverts. Each of the box culverts has a width of 4 feet and height of 6 feet with a headgate for controlling flow releases. The length from the upstream toe to the downstream toe of the earthen dam is 80 feet. This length results in 2 points for length. The total width of the culvert openings is 16 feet, while the channel width is 50 feet. Because the culvert opening width is less than the channel width, the Headworks receives 1 point for width. Because the flow through the culverts is controlled by gates, the difference in elevation between the pool upstream of the Headworks and downstream of the Headworks can be as much as 18 feet or the height of the earthen dam. Thus, the Headworks receives 2 points for drop. The Headworks does not have riprap or an apron in the downstream pool. With 2 points for length, 1 point for width, and 2 points for drop, the Headworks scores 5 points.

Table 5-2. Scoring of flashboard dams with boards in place

Due to their unique characteristics, seasonal flashboards (with flashboards installed) were scored using a separate point scale tied to these characteristics. The scoring breakdown is shown in Table 4-8 and described in Chapter 4. The highest possible score was 9 points (Table 5-2). . Cherryland, Panella, Lavaggi, McClean, Prato, and Clements Road flashboard dams all received 9 points. They had drops of over 3 feet with plunge pools less than 2 feet deep and exposed riprap downstream of the drop. Murphy Flashboard Dam had the lowest score with 3 points. It has a drop height of 3.6 feet, but with a plunge pool that is 7.4 feet deep and has no riprap downstream. The seasonal dams without scores are either remnants or are not being used during irrigation season.

Phase II Fish Passage Evaluation Results – Grouping

The scored structures were grouped for Phase II fish passage evaluation. There is at least one group for each structure type on each channel of the river. From each group, we selected one structure as a representative structure for modeling in HEC-RAS.

McAllen Road Bridge represents bridges on the Calaveras River (Table 5-3). Because of extensive riprap on the bed and banks, the McAllen Road Bridge presents the greatest degree of impairment to fish passage compared to other bridges on the Calaveras River.

Table 5-3. Grouped bridges on the Calaveras River

Fine Road Bridge represents bridges on Mormon Slough and the Stockton Diverting Canal (Table 5-4). Fine Road Bridge has a score of 0 as do the rest of the bridges in the group. Modeling Fine Road Bridge will show if there may be unexpected passage problems at bridges with a score of 0.

Table 5-4 Grouped bridges on Mormon Slough and Stockton Diverting Canal

Two bridges could not be grouped with the other bridges on Mormon Slough and Stockton Diverting Canal (Table 5-5). The Mormon Slough Railroad Bridge has an apron that spreads low flows into thin sheets of water between bridge piers. The apron and riprap at the site distinguish it from the other bridges, and it is necessary to create a HEC-RAS model of the bridge in order to determine what kind of barrier it is to fish passage. The Central California Traction Railroad Bridge has an apron, but also has a flume through the center of the apron. These features distinguish it from the other bridges, and a HEC-RAS model is necessary to determine what kind of barrier it is to fish passage. Because access to Duncan Road Driveway Bridge was denied, it was neither scored nor grouped (Table 5-6).

Table 5-5. Ungrouped bridges

Table 5-6. Ungrouped bridges not scored

Gotelli Low Flow Road Crossing (RM 6.2) was selected to represent low-flow road crossings on the Calaveras River that had a score of 3 (Table 5-7). Although Caprini Low Flow Road Crossing is on Mormon Slough, it was selected to represent McGurk Low Flow road crossing on the Calaveras River (Table 5-8). Both low-flow road crossings have aprons at the culvert outlets that significantly impair fish passage. The remaining low-flow road crossings were not grouped because they have unique site characteristics that require modeling in HEC-RAS to determine their impacts on fish passage (Table 5-9). Because access was denied to Williams Low-Flow Road Crossing, it was neither scored nor grouped (Table 5-10).

Table 5-7. Grouped low flow road crossings on the Calaveras River

Table 5-8. Grouped low flow road crossings with aprons

Table 5-9. Ungrouped low flow road crossings

Table 5-10. Ungrouped low flow road crossings not scored

Table 5-11 contains the scored permanent dams and weirs. CH2MHill is developing plans for fish passage at Bellota Weir. Because fish passage is being addressed at Bellota Weir, we did not develop a HEC-RAS model of the structure. We are developing conceptual designs for fish passage at the Calaveras Headworks. Hydraulic conditions at the structure will be analyzed as part of the design process. The Old DWR Stream Gage Weir is no longer used and should be removed. Additionally, the Concrete Slabs, the partial concrete structure near Pacific Avenue Bridge, and the rubble dam above Bellota no longer serve their original purpose and should be removed. If the McGurk Earth Dam has not completely washed away by the time upstream migration has started for spawning, then it is a significant barrier to fish passage. Rather than model the structure, we suggest either removing it or replacing it with a structure that can be removed completely when spawning is occurring.

Table 5-11. Scored permanent dams and weirs

Flashboard dams on the Calaveras River channel were divided into two groups. McAllen dam represents flashboard dams that have trapezoidal cross sections and removable flashboard guides (Table 5-12). Murphy dam represents the flashboard dams that have rectangular cross sections and permanent concrete flashboard guides (Table 5-13).

Table 5-12. Grouped flashboard dams (boards removed) with trapezoidal cross sections on the Calaveras River

Table 5-13. Grouped flashboard dams with rectangular cross sections on the Calaveras River

Flashboard dams on Mormon Slough and Stockton Diverting Canal also were divided into two groups. The division occurs at the confluence with Potter Creek. Lavaggi dam represents flashboard dams downstream of Potter Creek (Table 5-14). Piazza dam represents structures upstream of Potter Creek (Table 5-15). We split Mormon Slough/Stockton Diverting Canal flashboard dams into two groups because Potter Creek can have a significant impact on flow in Mormon Slough and therefore on fish passage during storm events. We did not divide the grouping of bridges on Mormon Slough and Stockton Diverting Canal at Potter Creek because bridges typically have less impact on fish passage.

Table 5-14. Grouped flashboard dams (boards removed) downstream of Potter Creek on Mormon Slough

Table 5-15. Grouped flashboard dams (boards removed) upstream of Potter Creek on Mormon Slough

Three flashboard dams were not included in any of the flashboard dam groups (Table 5-16). Clements Road, Cherryland, and Budiselich flashboard dams all scored higher than the rest of the flashboard dams. Each had multiple features that impacted fish passage and needed to be modeled in HEC-RAS such as excessive drop or large amounts of riprap.

Table 5-16. Ungrouped flashboard dams (boards removed)

Phase II Fish Passage Evaluation Results – Model Selection

We modeled structures that were representative of their grouping (Tables 5-3, 5-4, 5-7, 5-8, and 5-12 through 5-15) and also ungrouped structures with a score of 4 or higher (Tables 5-5, 5-9, 5-11, and 5-16). We did not model structures recommended for removal (some appear in Table 5-11). Structures were modeled in HEC-RAS. Appendix D provides performance summaries and velocity and depth curves based on original raw data. Here we present refined and enhanced model runs of the selected 17 structures, which we split into two groups. Eight structures were modeled in 2004; nine in 2005.

Appendix D Hydraulic Model Results

The representative structures selected for modeling were Fine Road Bridge, Gotelli Low Flow Road Crossing (RM 6.2), Lavaggi Flashboard Dam, McAllen Flashboard Dam, McAllen Road Bridge, Murphy Flashboard Dam, and Piazza Flashboard Dam. The ungrouped structures that scored 4 and higher and selected for modeling were Budiselich Flashboard Dam, Caprini Low Flow Road Crossing, Central California Traction Railroad Bridge, Cherryland Flashboard Dam, Clements Road Flashboard Dam, Fujinaka Low Flow Road Crossing, Hogan Low Flow Road Crossing, Hosie Low Flow Road Crossing, Mormon Slough Railroad Bridge, and Watkins Low Flow Road Crossing. The total number of structures selected for modeling is 17. We split them into two groups: 2004 modeled structures and 2005 modeled structures. The eight structures selected for modeling in 2004 were:

Stockton Diverting Canal
- Central California Traction Railroad Bridge
- Budiselich Flashboard Dam

Mormon Slough
- Caprini Low Flow Road Crossing
- Hogan Low Flow Road Crossing
- Hosie Low Flow Road Crossing
- Watkins Low Flow Road Crossing

Calaveras River
- Murphy Flashboard Dam
- Clements Road Flashboard Dam

We selected the following nine structures for modeling in spring 2005:

Mormon Slough
- Lavaggi Flashboard Dam
- Fujinaka Low Flow Road Crossing
- Mormon Slough Railroad Bridge
- Piazza Flashboard Dam
- Fine Road Bridge

Calaveras River
- Gotelli Low Flow Road Crossing (RM 6.2)
- McAllen Road Bridge
- McAllen Flashboard Dam
- Cherryland Flashboard Dam

Phase II Fish Passage Evaluation Results – Hydraulic Modeling

The modeling results from the 17 structures selected for hydraulic modeling are described in this section. The structures are presented for each modeling year from downstream to upstream, starting with structures on the Stockton Diverting Canal and Mormon Slough and concluding with structures on the Calaveras River downstream of the Calaveras Headworks. Site descriptions for all modeled structures are in Appendix A.

Appendix A Site Descriptions

Fish passage at all of the modeled structures is summarized in Table 5-17. The structures in the table are ordered according to their score from the Phase I evaluation.

Table 5-17. Percent of time with unimpaired passage at modeled structures

2004 Modeled Structures

None of the 2004 modeled structures allowed 100% passage during any of the three migration periods. Passage for adult Chinook was unimpaired less than 9% of the migration period at all of the 2004 modeled structures. Passage for adult *O. mykiss* was also poor with unimpaired passage less than about 22% of the migration period at all of the modeled structures. Juvenile passage was unimpaired about 50% of the migration period at Murphy Flashboard Dam, Central California Traction Railroad Bridge, and Hogan Low Flow Road Crossing. At the rest of the modeled structures, juvenile passage was unimpaired less than 30% of the migration period.

Riprap was often the feature that had the greatest impact on fish passage at the modeled structures. At Hosie Low Flow Road Crossing, Clements Road Flashboard Dam, Central California Traction Railroad Bridge, and Budiselich Flashboard Dam, insufficient depth over riprap significantly impaired fish passage. Velocities in excess of the criteria identified in Chapter 4 impaired fish passage at Caprini and Hogan low flow road crossings. Shallow depths over the structures at Murphy Flashboard Dam and Watkins Low Flow Road Crossing impaired fish passage.

Central California Traction Railroad Bridge

The Central California Traction Railroad Bridge (CCTRR) is on the Stockton Diverting Canal at river mile 1. The bridge has an apron of concrete poured over rocks and concrete pieces under it to protect the bridge piers from scour. A flume flows through the apron along the centerline of the channel (Photo 5-1). The combination of the apron, which acts as a weir, and the flume is challenging to model because the flow regimes and depths differ over the apron and in the flume, but with the use of calibration data the structure was successfully represented in HEC-RAS. The site description for CCTRR is included in Appendix A.

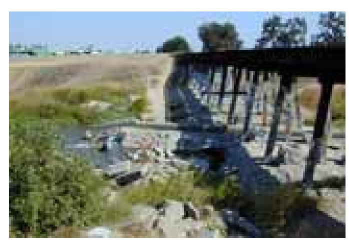


Photo 5-1. Central California Traction Railroad Bridge – Side view

A HEC-RAS model was developed for CCTRR from cross-section surveys taken upstream and downstream of the structure and from the measurements of the features described above. Manning’s n values ranged from 0.012 in the concrete flume to 0.12 over riprap. The model was calibrated using two flows: 111 cubic feet per second and 2,128 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the two calibration flows.

cfs = cubic feet per second

The HEC-RAS model was run under a wide range of flows, and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-2 and 5-3. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-1. The results of the Phase II fish passage evaluation at CCTRR are presented below.

Figure 5-1. Longitudinal profile for Central California Traction Railroad Bridge

Performance Summary

The depth criterion in the flume and over the weir at CCTRR is 1 foot for adult salmonids. This criterion is met at flume 1 and 2 at 30 cfs and higher (Figure 5-2). Flow is 1 foot deep over the weir when flow reaches 190 cfs. The depth criterion over riprap at CCTRR is 2 feet for adult salmonids. At riprap 1 this criterion is met at 210 cfs or greater, and at riprap 2 this criterion is met at flows greater than 160 cfs. Thus, the depth criterion for unimpaired adult fish passage at CCTRR is met when flow is 210 cfs or greater.

Figure 5-2. Depth curves for Central California Traction Railroad Bridge

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. The structure length for fish passing through the flume is different than the structure length for fish passing over the weir under the bridge. Fish can pass either through the flume or over the weir at flows 40 cfs or above. For fish passing through the flume, at flows less than 190 cfs, the velocity criterion is 4 feet per second (Figure 5-3). For fish passing through the flume, the maximum allowable velocity increases to 5 fps at flows greater than 190 cfs. For fish passing over the weir, the velocity criterion is 5 fps for flows less than 240 cfs, 6 fps for flows between 240 cfs and 390 cfs, and 8 fps for flows greater than 390 cfs. Velocities at flume 1 and 2 exceed criteria between 12 and 1970 cfs. Velocity over the weir is less than the maximum allowable velocity at all modeled flows. Velocities at ripraps 1 and 2 are also less than the maximum allowable velocity at all modeled flows. Thus, the velocity criterion for unimpaired adult fish passage at CCTRR is met in the flume when flow is less than 12 cfs or over the weir at flows 40 cfs and above.

Figure 5-3. Velocity curves for Central California Traction Railroad Bridge

fps = feet per second

Adult salmonid passage is impaired most at riprap 1 where the depth criterion is not met until flow is 210 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at CCTRR. Because adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for CCTRR are the ranges defined in Table 4-10 for the Stockton Diverting Canal.

[DFG] California Department of Fish and Game. 2002. Culvert Criteria for Fish Passage. The Resources Agency, Sacramento. 15p.

Table 5-18 shows adult Chinook passage performance at CCTRR. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 978 cfs. However, adult Chinook have unimpaired passage at CCTRR only at 210 cfs and above. From the table, it is apparent that CCTRR is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 5% of the time during their migration period (Figure 5-4). In the 18 adult Chinook migration seasons that were analyzed for structures on the Stockton Diverting Canal, flows reached or exceeded 210 cfs only during 9 of the migration seasons.

Table 5-18. Adult Chinook passage performance at CCTRR

Figure 5-4. Stockton Diverting Canal flow duration curve showing adult Chinook passage performance at CCTRR, Sep through Dec

Table 5-19 shows adult *O. mykiss* passage performance at CCTRR. According to DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 6 and 4,540 cfs. However, adult *O. mykiss* have unimpaired passage at CCTRR at flows at or above 210 cfs. From the table, it is apparent that CCTRR is a temporal barrier to adult *O. mykiss*. Adult *O. mykiss* have unimpaired passage about 18% of the time during their migration period (Figure 5-5). In the 18 adult *O. mykiss* migration seasons that were analyzed for structures on the Stockton Diverting Canal, flows reached or exceeded 210 cfs during 16 of the migration seasons.

Table 5-19. Adult *O. mykiss* passage performance at CCTRR

Figure 5-5. Stockton Diverting Canal flow duration curve showing adult *O. mykiss* passage performance at CCTRR, Oct through Mar

The depth criterion in the flume and over the weir at CCTRR is 0.5 feet for juvenile salmonids. This criterion is not met until 11 cfs in the flume and until 75 cfs over the weir (see Figure 5-2). The depth criterion over riprap at CCTRR is 1 foot for juvenile salmonids. At riprap 1, this criterion is met at 10 cfs or greater, while at riprap 2 this criterion is met at flows greater than 5 cfs. Thus, the depth criterion for unimpaired juvenile fish passage at CCTRR is met when flow is 11 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at CCTRR. These lower and upper flows are listed in Table 4-10 for Stockton Diverting Canal. The passage flow range for juveniles is between 1 and 847 cfs. Table 5-20 shows juvenile salmonid passage performance at CCTRR. Juvenile salmonids have unimpaired passage at CCTRR only when flow is 11 cfs or higher. It is apparent from the table that CCTRR is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 46% of the time during their migration period, as shown in Figure 5-6. In the 18 juvenile salmonid migration seasons that were analyzed for structures on the Stockton Diverting Canal, flows reached or exceeded 11 cfs during all of the migration seasons.

Table 5-20. Juvenile salmonid passage performance at CCTRR

Figure 5-6. Stockton Diverting Canal flow duration curve showing juvenile salmonid passage performance at CCTRR, Jan through June

Budiselich Flashboard Dam

Budiselich Flashboard Dam is on the Stockton Diverting Canal near river mile 2. The dam consists of a concrete base between two concrete abutments (Photo 5-2). Riprap extends downstream of the dam base. The site description for Budiselich is in Appendix A.

Photo 5-2. Budiselich Flashboard Dam – View from left bank of base with riprap downstream

A HEC-RAS model was developed for Budiselich Flashboard Dam from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning's n values ranged from 0.02 over the concrete dam base to 0.07 over riprap and dense vegetation. The model was calibrated using three flows: 116 cfs, 267 cfs, and 2,240 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the three calibration flows.

The HEC-RAS model was run under a wide range of flows. Results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-8 and 5-9. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-7. The results of the Phase II fish passage evaluation at Budiselich are presented below.

Figure 5-7. Longitudinal profile for Budiselich FBD

Performance Summary

The depth criterion over the dam base at Budiselich Flashboard Dam is 1 foot for adult salmonids. This criterion is not met until 190 cfs (Figure 5-8). The depth criterion over riprap at Budiselich Flashboard Dam is 2 feet for adult salmonids. At riprap 1 this criterion is met at 570 cfs or greater, and at riprap 2 this criterion is met at flows greater than 120 cfs. Flow is 2 feet deep at riprap 3 when flows exceed 100 cfs. Thus, the depth criterion for unimpaired adult fish passage at Budiselich Flashboard Dam is met when flow is 570 cfs or greater.

Figure 5-8. Depth curves for Budiselich FBD

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At flows less than 120 cfs, the velocity must be less than 6 fps (Figure 5-9). As flow increases and depth over the riprap downstream of the dam increases, the allowable velocity also increases. Between 120 and 160 cfs, the maximum velocity allowed for unimpaired fish passage is 8 fps, and at flows greater than 160 cfs, the velocity criterion increases to 10 fps. Velocity over the dam base meets the velocity criterion at all modeled flows. Velocity at ripraps 1 and 2 also meet the velocity criterion at all modeled flows. Velocity at riprap 3 exceeds the maximum allowable velocity between 45 and 85 cfs. Thus the velocity criterion is met at flows less than 45 cfs and flows greater than 85 cfs.

Figure 5-9. Velocity curves for Budiselich FBD

Adult salmonid passage is impaired most at riprap 1 where the depth criterion is not met until flow is 570 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Budiselich Flashboard Dam. Because adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Budiselich Flashboard Dam are the ranges defined in Table 4-10 for Stockton Diverting Canal.

Table 5-21 shows adult Chinook passage performance at Budiselich. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 978 cfs. However, adult Chinook have unimpaired passage at Budiselich only at 570 cfs and above. From the table, it is apparent that Budiselich is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 2% of the time during their migration period (Figure 5-10). In the 18 adult Chinook migration seasons that were analyzed for structures on the Stockton Diverting Canal, flows reached or exceeded 570 cfs only during 7 of the migration seasons.

Table 5-21. Adult Chinook passage performance at Budiselich FBD

Figure 5-10. Stockton Diverting Canal flow duration curve showing adult Chinook passage performance at Budiselich FBD, Sep through Dec

Table 5-22 shows adult *O. mykiss* passage performance at Budiselich. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 6 and 4,540 cfs. However, adult *O. mykiss* have unimpaired passage at Budiselich only at flows of 570 cfs and greater. From the table, it is apparent that Budiselich is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 12% of the time during their migration period (Figure 5-11). In the 18 adult *O. mykiss* migration seasons that were analyzed for structures on the Stockton Diverting Canal, flows reached or exceeded 570 cfs during 16 of the migration seasons.

Table 5-22. Adult *O. mykiss* passage performance at Budiselich FBD

Figure 5-11. Stockton Diverting Canal flow duration curve showing adult *O. mykiss* passage performance at Budiselich FBD, Oct through Mar

The depth criterion over the dam base at Budiselich Flashboard Dam is 0.5 feet for juvenile salmonids. This criterion is not met until 80 cfs (see Figure 5-8). The depth criterion over riprap at Budiselich is 1 foot for juvenile salmonids. At riprap 1, this criterion is met at 170 cfs or greater, and at riprap 2 this criterion is met at flows greater than 30 cfs. Flow is 1 foot deep at riprap 3 when flows exceed 85 cfs. Thus, the depth criterion for unimpaired juvenile fish passage at Budiselich Flashboard Dam is met when flow is 170 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles because we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Budiselich Flashboard Dam. These lower and upper flows are listed in Table 4-10 for Stockton Diverting Canal. The passage flow range for juveniles is between 1 and 847 cfs. Table 5-23 shows juvenile salmonid passage performance at Budiselich. Juvenile salmonids have unimpaired passage at Budiselich only at 170 cfs and higher. It is apparent from the table that Budiselich is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 18% of the time during their migration period, as shown in Figure 5-12. In the 18 juvenile salmonid migration seasons that were analyzed for structures on the Stockton Diverting Canal, flows reached or exceeded 170 cfs during 16 of the migration seasons

Table 5-23. Juvenile salmonid passage performance at Budiselich FBD

Figure 5-12. Stockton Diverting Canal flow duration curve showing juvenile salmonid passage performance at Budiselich FBD, Jan through June

Caprini Low Flow Road Crossing

Caprini Low Flow Road Crossing (LFC) is on Mormon Slough near river mile 8. The crossing is composed of a concrete road prism overlaying three corrugated metal pipe culverts (Photo 5-3). There is an irregular concrete apron on the upstream side of the crossing and a uniform concrete apron downstream of the crossing. There is riprap on the banks downstream of the crossing and on the bed downstream of the downstream apron. The site description for Caprini is in Appendix A.

Photo 5-3. Caprini Low Flow Road Crossing

A HEC-RAS model was developed for Caprini LFC from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning's n values ranged from 0.015 over the concrete road prism to 0.08 over riprap. The model was calibrated using two flows: 208 cfs and 1900 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the two calibration flows.

LFC = low flow road crossing

The HEC-RAS model was run under a wide range of flows, and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-14 and 5-15. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-13. The results of the Phase II fish passage evaluation at Caprini are presented below.

Figure 5-13. Longitudinal profile for Caprini LFC

Performance Summary

The depth criterion over the apron and road crossing and through the culverts at Caprini is 1 foot for adult salmonids. This criterion is met at 35 cfs and higher in the culverts (Figure 5-14). The depth criterion is met at flows 75 cfs or greater over the apron and at flows 350 cfs or greater over the road

Figure 5-14. Depth curves for Caprini LFC

crossing. The depth criterion over riprap at Caprini is 2 feet for adult salmonids. This criterion for riprap is met at 400 cfs or greater. Thus, the depth criterion for unimpaired adult fish passage at Caprini LFC is met when flow is 400 cfs or greater.

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At flows less than 50 cfs, the velocity must be less than 5 fps (Figure 5-15). As flow increases and depth over the riprap downstream of the crossing increases, the allowable velocity also increases. Between 50 and 150 cfs, the maximum velocity allowed for unimpaired fish passage is 6 fps. At flows between 150 and 350 cfs, the velocity criterion increases to 8 fps; and at flows greater than 350 cfs, the velocity criterion increases to 10 fps. Velocity in the culverts meets the velocity criterion at flows less than 20 cfs and flows greater than 450 cfs. Velocity over the road crossing meets the criterion at all flows that overtop the crossing. Velocity over the apron exceeds the criterion between 100 and 150 cfs, 230 and 350 cfs, and 450 and 630 cfs. Velocity over the riprap exceeds the maximum allowable velocity between 30 and 730 cfs. Thus, the velocity criterion is met at flows less than 20 cfs and flows greater than 730 cfs.

Figure 5-15. Velocity curves for Caprini LFC

Adult salmonid passage is impaired most over the riprap where the velocity criterion is not met until flow is 730 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Caprini LFC. Because adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Caprini are the ranges defined in Table 4-10 for Mormon Slough downstream of Mormon Slough Railroad (MSRR) Bridge.

Table 5-24 shows adult Chinook passage performance at Caprini. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 978 cfs. However, adult Chinook have unimpaired passage at Caprini only at 730 cfs and above. From the table, it is apparent that Caprini is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 1% of the time during their migration period (Figure 5-16). In the 18 adult Chinook migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 730 cfs only during 6 of the migration seasons.

Table 5-24. Adult Chinook passage performance at Caprini LFC

Figure 5-16. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Caprini LFC, Sep through Dec

Table 5-25 shows adult *O. mykiss* passage performance at Caprini. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 6 and 4540 cfs. However, adult *O. mykiss* have unimpaired passage at Caprini only at flows of 730 cfs and higher. From the table, it is apparent that Caprini is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 10% of the time during their migration period (Figure 5-17). In the 18 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 730 cfs during 15 of the migration seasons.

Table 5-25. Adult O. mykiss passage performance at Caprini LFC

Figure 5-17. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Caprini LFC, Oct through Mar

The depth criterion through the culverts, over the road crossing, and over the apron at Caprini LFC is 0.5 feet for juvenile salmonids. This criterion is met at 9 cfs in the culverts, at 230 cfs over the crossing, and

22 cfs on the apron (see Figure 5-14). The depth criterion over riprap at Caprini is 1 foot for juvenile salmonids. Over the riprap, this criterion is met at 120 cfs or greater. Thus, the depth criterion for unimpaired juvenile fish passage at Caprini LFC is met when flow is 120 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Caprini LFC. These lower and upper flows are listed in Table 4-10 for Mormon Slough downstream of MSRR Bridge. The passage flow range for juveniles is between 1 and 847 cfs. Table 5-26 shows juvenile salmonid passage performance at Caprini. Juvenile salmonids have unimpaired passage at Caprini only when flow is 120 cfs or higher. It is apparent from the table that Caprini is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 20% of the time during their migration period, as shown in Figure 5-18. In the 18 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 120 cfs during 17 of the migration seasons.

Table 5-26. Juvenile salmonid passage performance at Caprini LFC

Figure 5-18. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Caprini LFC, Jan through June

Hogan Low Flow Road Crossing

Hogan Low Flow Road Crossing is on Mormon Slough at river mile 8.4. The crossing is made of a rough, irregular concrete road prism poured over three reinforced concrete pipes of different sizes, lengths, elevations, and slopes (Photo 5-4). There is riprap on the bed downstream of the crossing. The site description for Hogan is in Appendix A.

Photo 5-4. Hogan Low Flow Road Crossing

A HEC-RAS model was developed for Hogan LFC from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning’s n values ranged from 0.012 in the concrete culverts to 0.08 on the vegetated banks. The model was calibrated using two flows: 208 cfs and 1980 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the two calibration flows.

The HEC-RAS model was run under a wide range of flows. Results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-20 and 5-21. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-19. The results of the Phase II fish passage evaluation at Hogan are presented below.

Figure 5-19. Longitudinal profile at Hogan LFC

<u>Performance Summary</u>

The depth criterion through the culverts and over the road crossing at Hogan is 1 foot for adult salmonids. This criterion is met at 40 cfs and above in the culverts (Figure 5-20). The depth criterion is met at flows 250 cfs or greater over the road crossing. The depth criterion over riprap at Hogan is 2 feet for adult salmonids. At riprap 1, this criterion is met at 20 cfs or greater. The depth criterion is met at riprap 2 for all flows. Thus, the depth criterion for unimpaired adult fish passage at Hogan LFC is met through the culverts when flow is 37 cfs or greater and over the crossing when flow is 250 cfs or greater.

Figure 5-20. Depth curves for Hogan LFC

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. The structure length for fish passing through culverts 1 and 2 is different than the structure length for fish passing through culvert 3 or over the road crossing. Depending on the flow depth, fish can swim through any of the culverts or over the road crossing to pass Hogan. For fish passing through culverts 1 and 2, the velocity criterion is 5 fps at all flows (Figure 5-21). The maximum allowable velocity for fish passing through culvert 3 is 5 fps for flows less than 25 cfs. The maximum allowable velocity in culvert 3 increases to 6 fps at flows greater than 25 cfs. For fish passing over the crossing, the velocity criterion is 6 fps for flows less than 240 cfs and 8 fps for flows greater than 240 cfs. Velocity in culvert 1 exceeds the criterion between 40 and 1200 cfs. Velocity in culvert 2 exceeds the criterion between 3 and 1200 cfs. Velocity in culvert 3 exceeds the criterion between 69 and 1100 cfs. Velocity over the road crossing is less than the maximum allowable velocity at all flows that overtop the road. Velocities at ripraps 1 and 2 are less than the maximum allowable velocity at all modeled flows. Thus, the velocity criterion for unimpaired adult fish passage at Hogan is met through the culverts when flow is less than 69 cfs or over the weir at flows 100 cfs and above.

Figure 5-21. Velocity curves for Hogan LFC

Because of the multiple paths available to fish to pass Hogan LFC, passage opportunities will be summarized for each path. Adult salmonid passage is unimpaired through culverts 1 and 2 for flows greater than 1150 cfs. Adult salmonids have unimpaired passage through culvert 3 between 37 and 69 cfs and flows above 1070 cfs. Adult salmonids have unimpaired passage over the crossing at flows above 250 cfs. In summary, adult salmonids have unimpaired passage past Hogan LFC between 37 and 69 cfs and at flows 250 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Hogan LFC. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Hogan are the ranges defined in Table 4-10 for Mormon Slough downstream of MSRR Bridge.

Table 5-27 shows adult Chinook passage performance at Hogan. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 978 cfs. However, adult Chinook have unimpaired passage at Hogan only between 37 cfs and 69 cfs and at 245 cfs and above. From the table, it is apparent that Hogan is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 8% of the time during their migration period (Figure 5-22). In the 18 adult Chinook migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 37 cfs during 15 of the migration seasons.

Table 5-27. Adult Chinook passage performance at Hogan LFC

Figure 5-22. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Hogan LFC, Sep through Dec

Table 5-28 shows adult *O. mykiss* passage performance at Hogan. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 6 and 4,540 cfs. However, adult *O. mykiss* have unimpaired passage at Hogan between 37 cfs and 69 cfs and at 245 cfs and higher. From the table, it is apparent that Hogan is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 22% of the time during their migration period (Figure 5-23). In the 18 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough

Table 5-28. Adult *O. mykiss* passage performance at Hogan LFC

Figure 5-23. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Hogan LFC, Oct through Mar

downstream of MSRR Bridge, flows reached or exceeded 37 cfs during 17 of the migration seasons.

The depth criterion through the culverts and over the road crossing at Hogan LFC is 0.5 feet for juvenile salmonids. This criterion is met at 14 cfs in culvert 1, 6 cfs in culvert 2, 15 cfs in culvert 3, and at 160 cfs over the crossing (see Figure 5-20). The depth criterion over riprap at Hogan is 1 foot for juvenile salmonids. Over riprap 1 and 2, this criterion is met at all modeled flows. Thus, the depth criterion for unimpaired juvenile fish passage at Hogan LFC is met when flow is 6 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Hogan LFC. These lower and upper flows are listed in Table 4-10 for Mormon Slough downstream of MSRR Bridge. The passage flow range for juveniles is between 1 and 847 cfs. Table 5-29 shows juvenile salmonid passage performance at Hogan. Juvenile salmonids have unimpaired passage at Hogan only at 6 cfs and above. It is apparent from the table that Hogan is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 56% of the time during their migration period, as shown in Figure 5-24. In the 18 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 6 cfs during all of the migration seasons.

Table 5-29. Juvenile salmonid passage performance at Hogan LFC

Figure 5-24. Mormon Slough downstream of MSRR Bridge duration curve showing juvenile salmonid passage performance at Hogan LFC, Jan through June flow

Hosie Low Flow Road Crossing

Hosie Low Flow Road Crossing is on Mormon Slough at river mile 13.2. The crossing is a concrete road prism with no culverts (Photo 5-5). There is riprap on the bed downstream of the crossing. The site description for Hosie is in Appendix A.

Photo 5-5. Hosie Low Flow Road Crossing

A HEC-RAS model was developed for Hosie LFC from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning’s n values ranged from 0.02 over the crossing to 0.1 on the vegetated banks. The model was calibrated using three flows: 112 cfs, 162 cfs, and 1,800 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the three calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-26 and 5-27. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-25. The results of the Phase II fish passage evaluation at Hosie are presented below.

Figure 5-25. Longitudinal profile at Hosie LFC

Performance Summary

The depth criterion over the crossing at Hosie LFC is 1 foot for adult salmonids. This criterion is not met until 320 cfs (Figure 5-26). The depth criterion over riprap at Hosie is 2 feet for adult salmonids. At riprap 2 this criterion is met at 360 cfs or greater, and at riprap 3 this criterion is met at flows greater than 460 cfs. Thus, the depth criterion for unimpaired adult fish passage at Hosie LFC is met when flow is 460 cfs or greater.

Figure 5-26. Depth curves for Hosie LFC

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At flows less than 190 cfs, the velocity must be less than 6 fps (Figure 5-27). As flow increases and depth over the riprap downstream of the dam increases, the allowable velocity also increases. Between 190 and 480 cfs, the maximum velocity allowed for unimpaired fish passage is 8 fps, and at flows greater than 480 cfs, the velocity criterion increases to 10 fps. Velocity over the crossing and over riprap 2 meets the velocity criterion at all modeled flows. The velocity criterion is met at riprap 3 when flow is less than 100 cfs or greater than 190 cfs. Thus the velocity criterion is met below 100 cfs and above 190 cfs.

Figure 5-27. Velocity curves for Hosie LFC

Adult salmonid passage is impaired most over the riprap where the depth criterion is not met until flow is 460 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Hosie LFC. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Hosie LFC are the ranges defined in Table 4-10 for Mormon Slough upstream of MSRR Bridge.

Table 5-30 shows adult Chinook passage performance at Hosie. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 15 and 1,590 cfs. However, adult Chinook have unimpaired passage at Hosie only at 460 cfs and higher. From the table, it is apparent that Hosie is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 3% of the time during their migration period (Figure 5-28). In the 20 adult Chinook migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 460 cfs only during 10 of the migration seasons.

Table 5-30. Adult Chinook passage performance at Hosie LFC

Figure 5-28. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Hosie LFC, Septhrough Dec

Table 5-31 shows adult *O. mykiss* passage performance at Hosie. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 19 and 5460 cfs. However, adult *O. mykiss* have unimpaired passage at Hosie only when flow is 460 cfs and higher. From the table, it is apparent that Hosie is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 14% of the time during their migration period (Figure 5-29). In the 21 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 460 cfs during 20 of the migration seasons.

Table 5-31. Adult O. mykiss passage performance at Hosie LFC

Figure 5-29. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult O. mykiss passage performance at Hosie LFC, Oct through Mar

The depth criterion over the road crossing at Hosie is 0.5 feet for juvenile salmonids. This criterion is not met until 100 cfs (see Figure 5-26). The depth criterion over riprap at Hosie is 1 foot for juvenile salmonids. At riprap 2, this criterion is met at 60 cfs or greater, while at riprap 3 this criterion is met at flows greater than 80 cfs. Thus, the depth criterion for unimpaired juvenile fish passage at Hosie is met when flow is 100 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Hosie LFC. These lower and upper flows are listed in Table 4-10 for Mormon Slough upstream of MSRR Bridge. The passage flow range for juveniles is between 1 and 1,248 cfs. Table 5-32 shows juvenile salmonid passage performance at Hosie. Juvenile salmonids have unimpaired passage at Hosie only at 100 cfs and above. It is apparent from the table that Hosie is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 30% of the time during their migration period, as shown in Figure 5-30. In the 21 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 100 cfs during 20 of the migration seasons.

Table 5-32. Juvenile salmonid passage performance at Hosie LFC

Figure 5-30. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Hosie LFC, Jan through June

Watkins Low Flow Road Crossing

Watkins Low Flow Road Crossing is on Mormon Slough near river mile 19. The crossing is a concrete road prism (Photo 5-6). There is a corroded corrugated metal pipe culvert that is mostly filled with sediment through the crossing. The bed is lined with riprap downstream of the structure. The site description for Watkins is in Appendix A.

Photo 5-6. Watkins Low Flow Road Crossing

A HEC-RAS model was developed for Watkins LFC from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning's n values ranged from 0.01 over the crossing to 0.1 on the vegetated banks. The model was calibrated using four flows: 129 cfs, 168 cfs, 42 cfs, and 1,520 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the four calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-32 and 5-33. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-31. The results of the Phase II fish passage evaluation at Watkins are presented below.

Figure 5-31. Longitudinal profile for Watkins LFC

<u>Performance Summary</u>

The depth criterion over the crossing at Watkins LFC is 1 foot for adult salmonids. This criterion is not met until 380 cfs (Figure 5-32). The depth criterion over riprap at Watkins is 2 feet for adult salmonids. At riprap 1 this criterion is met at 310 cfs or greater, while at riprap 2 this criterion is met at flows greater than 170 cfs. Thus, the depth criterion for unimpaired adult fish passage at Watkins LFC is met when flow is 380 cfs or greater.

Figure 5-32. Depth curves for Watkins LFC

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At flows less than 60 cfs, the velocity must be less than 6 fps (Figure 5-33). As flow increases and depth over the riprap downstream of the dam increases, the allowable velocity also increases. At flows greater than 62 cfs, the velocity criterion increases to

Figure 5-33. Velocity curves for Watkins LFC

8 fps. Velocity over the crossing and over both riprap sections meets the velocity criterion at all modeled flows. Thus the velocity criterion is met at all modeled flows.

Adult salmonid passage is impaired most over the crossing where the depth criterion is not met until flow is 380 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Watkins LFC. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Watkins LFC are the ranges defined in Table 4-10 for Mormon Slough upstream of MSRR Bridge.

Table 5-33 shows adult Chinook passage performance at Watkins. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 15 and 1590 cfs. However, adult Chinook have unimpaired passage at Watkins only at 380 cfs and greater. From the table, it is apparent that Watkins is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 5% of the time during their migration period (Figure 5-34). In the 20 adult Chinook migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 380 cfs only during 10 of the migration seasons.

Table 5-33. Adult Chinook passage performance at Watkins LFC

Figure 5-34. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Watkins LFC, Sep through Dec

Table 5-34 shows adult *O. mykiss* passage performance at Watkins. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 19 and 5460 cfs. However, adult *O. mykiss* have unimpaired passage at Watkins only when flow is 380 cfs and higher. From the table, it is apparent that Watkins is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 16% of the time during their migration period (Figure 5-35). In the 21 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 380 cfs during 20 of the migration seasons.

Table 5-34. Adult *O. mykiss* passage performance at Watkins LFC

Figure 5-35. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Watkins LFC, Oc through Mar

The depth criterion over the road crossing at Watkins is 0.5 feet for juvenile salmonids. This criterion is not met until 120 cfs (see Figure 5-32). The depth criterion over riprap at Watkins is 1 foot for juvenile salmonids. At riprap 1, this criterion is met at 70 cfs or greater, while at riprap 2 this criterion is met at flows greater than 30 cfs. Thus, the depth criterion for unimpaired juvenile fish passage at Watkins is met when flow is 120 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Watkins LFC. These lower and upper flows are listed in Table 4-10 for Mormon Slough upstream of Mormon Slough Railroad Bridge. The passage flow range for juveniles is between 1 and 1,248 cfs. Table 5-35 shows juvenile salmonid passage performance at Watkins. Juvenile salmonids have unimpaired passage at Watkins only at 120 cfs and above. It is apparent from the table that Watkins is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 27% of the time during their migration period, as shown in Figure 5-36. In the 21 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 120 cfs during 20 of the migration seasons.

Table 5-35. Juvenile salmonid passage performance at Watkins LFC

Figure 5-36. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Watkins LFC, Jan through June

Murphy Flashboard Dam

Murphy flashboard dam is located on the Calaveras River at river mile 12.5. The dam has permanent concrete abutments with guide slots for flashboards (Photo 5-7). During non-irrigation season one or two flashboards are left in place in each of the four bays. The site description for Murphy is in Appendix A.

Photo 5-7. Murphy Flashboard Dam

A HEC-RAS model was developed for Murphy flashboard dam from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning's n values ranged from 0.02 at the structure to 0.1 on the vegetated banks. The model was calibrated using two flows: 15 cfs and 48 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the two calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-38 and 5-39. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-37. The results of the Phase II fish passage evaluation at Murphy are presented below.

Figure 5-37. Longitudinal profile for Murphy FBD

Performance Summary

The depth criterion over the dam and in the channel at Murphy flashboard dam is 1 foot for adult salmonids. At dam 1, this criterion is met at flows 26 cfs or greater. At dam 2, this criterion is met at all modeled flows. At channel 1, this criterion is met at 9 cfs and greater, while at channel 2, the depth criterion is met at all modeled flows (Figure 5-38). Thus, the depth criterion for unimpaired adult fish passage at Murphy flashboard dam is met when flow is 26 cfs or greater.

Figure 5-38. Depth curves for Murphy FBD

The velocity criterion for adult salmonids at Murphy flashboard dam is 10 fps (Figure 5-39). Velocity at the dam sections and at the channel sections meets the velocity criterion at all modeled flows. Thus the velocity criterion is met at all modeled flows.

Figure 5-39. Velocity curves for Murphy FBD

Adult salmonid passage is impaired most at dam 1 where the depth criterion is not met until flow is 26 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Murphy flashboard dam. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Murphy flashboard dam are the ranges defined in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal.

Table 5-36. Adult Chinook passage performance at Murphy FBD

Table 5-36 shows adult Chinook passage performance at Murphy. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 97 cfs. However, adult Chinook have unimpaired passage at Murphy only at 26 cfs and above. From the table, it is apparent that Murphy is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 7% of the time during their migration period (Figure 5-40). In the 22 adult Chinook migration seasons that were analyzed for structures on the Calaveras River downstream of the

Figure 5-40. Calaveras River from the Headworks to SDC flow duration curve showing adult Chinook passage performance at Murphy FBD, Sep through Dec

Headworks, flows reached or exceeded 26 cfs during 19 of the migration seasons.

Table 5-37 shows adult *O. mykiss* passage performance at Murphy. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 3 and 166 cfs. However, adult *O. mykiss* have unimpaired passage at Murphy only at 26 cfs and greater. From the table, it is apparent that Murphy is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 12% of the time during their migration period (Figure 5-41). In the 22 adult *O. mykiss* migration seasons that were analyzed for structures on the Calaveras River downstream of the Headworks, flows reached or exceeded 26 cfs during 20 of the migration seasons.

Table 5-37. Adult *O. mykiss* passage performance at Murphy FBD

Figure 5-41. Calaveras River from the Headworks to SDC duration curve showing adult *O. mykiss* passage performance at Murphy FBD, Oct through Mar flow

The depth criterion over the dam and in the channel at Murphy flashboard dam is 0.5 feet for juvenile salmonids. This criterion is met for all flows at dam 2 and channel 2. The depth criterion is met at 1.5 cfs at channel 1 and at 8 cfs at dam 1 (see Figure 5-38). Thus, the depth criterion for unimpaired juvenile fish passage at Murphy is met when flow is 8 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Murphy flashboard dam. These lower and upper flows are listed in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal. The passage flow range for juveniles is between 1 cfs and 38 cfs. Table 5-38 shows juvenile salmonid passage performance at Murphy. Juvenile salmonids have unimpaired passage at Murphy only when flow is 8 cfs or higher. It is apparent from the table that Murphy is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 55% of the time during their migration period, as shown in Figure 5-42. In the 22 juvenile salmonid migration seasons that were analyzed for structures on the Calaveras River downstream of the Headworks, flows reached or exceeded 8 cfs during all of the migration seasons.

Table 5-38. Juvenile salmonid passage performance at Murphy FBD

Figure 5-42. Calaveras River from the Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Murphy FBD, Jan through June

Clements Road Flashboard Dam

Clements Road Flashboard Dam is on the Calaveras River at river mile 21.5. The structure is a concrete box culvert with two bays that functions as a road crossing and a flashboard dam (Photo 5-8). An apron extends downstream from the culvert outlet. The apron drops onto riprap lining the beds. The site description for Clements is in Appendix A.

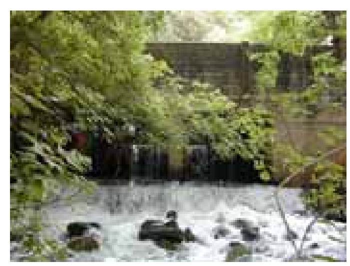


Photo 5-8. Clements Road Flashboard Dam with boards in place

A HEC-RAS model was developed for Clements Road flashboard dam from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning's n values ranged from 0.013 at the structure to 0.1 on the vegetated banks. The model was calibrated using two flows: 18 cfs and 48 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the two calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-44 and 5-45. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-43. The results of the Phase II fish passage evaluation at Clements Road are presented below.

Figure 5-43. Longitudinal profile at Clements Road FBD

Performance Summary

The depth criterion at the crossing and over the apron at Clements Road Flashboard Dam is 1 foot for adult salmonids. At the crossing, this criterion is met at flows 50 cfs or greater (Figure 5-44). Over the apron, this criterion is also met at 50 cfs or greater. The depth criterion over riprap at Clements is 2 feet for adult salmonids. At riprap 1 this criterion is met at 60 cfs or greater, while at riprap 2 this criterion is met at flows greater than 67 cfs. The depth criterion is met at riprap 3 at 34 cfs. Thus, the depth criterion for unimpaired adult fish passage at Clements Road flashboard dam is met when flow is 67 cfs or greater.

Figure 5-44. Depth curves for Clements Road FBD

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At Clements, at flows less than 13 cfs, the velocity must be less than 5 fps (Figure 5-45). As discussed in Chapter 4, as flow increases and depth over the riprap downstream of the dam increases, the allowable velocity also increases. Between 13 and 63 cfs, the velocity criterion increases to 6 fps, and at flows greater than 63 cfs the velocity criterion increases to 8 fps. Velocity at the crossing, apron, and all 3 riprap sections meets the velocity criterion at all modeled flows. Thus the velocity criterion is met at all modeled flows.

Figure 5-45. Velocity curves for Clements Road FBD

Adult salmonid passage is impaired most at riprap 2 where the depth criterion is not met until flow is 67 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Clements Road flashboard dam. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Clements Road flashboard dam are the ranges defined in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal.

Table 5-39 shows adult Chinook passage performance at Clements. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 97 cfs. However, adult Chinook have unimpaired passage at Clements only at 67 cfs and above. From the table, it is apparent that Clements is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 2% of the time during their migration period (Figure 5-46). In the 22 adult Chinook migration seasons that were analyzed for structures on the Calaveras River downstream of the Headworks, flows reached or exceeded 67 cfs only during 4 of the migration seasons.

Table 5-39. Adult Chinook passage performance at Clements Road FBD

Figure 5-46. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at Clements FBD, Sept through Dec

Table 5-40 shows adult *O. mykiss* passage performance at Clements. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 3 and 166 cfs. However, adult *O. mykiss* have unimpaired passage at Clements only when flow is 67 cfs or higher. From the table, it is apparent that Clements is a temporal barrier to adult *O. mykiss*

Table 5-40. Adult *O. mykiss* passage performance at Clements Road FBD

passage. Adult *O. mykiss* have unimpaired passage about 5% of the time during their migration period (Figure 5-47). In the 22 adult *O. mykiss* migration seasons that were analyzed for structures on the Calaveras River downstream of the Headworks, flows reached or exceeded 67 cfs only during 14 of the migration seasons.

Figure 5-47. Calaveras River Headworks to SDC flow duration curve showing adult *O. mykiss* passage performance at Clements FBD, Oct through Mar

The depth criterion over the dam and in the channel at Clements Road Flashboard Dam is 0.5 feet for juvenile salmonids. This criterion is met at the crossing and apron at 22 cfs. The depth criterion is met at all flows at riprap 1, at 30 cfs at riprap 2, and at 17 cfs at riprap 3 (see Figure 5-44). Thus, the depth criterion for unimpaired juvenile fish passage at Clements is met when flow is 30 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Clements Road Flashboard Dam. These lower and upper flows are listed in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal. The passage flow range for juveniles is between 1 and 38 cfs. Table 5-41 shows juvenile salmonid passage performance at Clements. Juvenile salmonids have unimpaired passage at Clements only at 30 cfs or higher. It is apparent from the table that Clements is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 15% of the time during their migration period, as shown in Figure 5-48. In the 22 juvenile salmonid migration seasons that were analyzed for structures on the Calaveras River downstream of the Headworks, flows reached or exceeded 30 cfs during all of the migration seasons.

Table 5-41. Juvenile salmonid passage performance at Clements Road FBD

Figure 5-48. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Clements FBD, Jan through June

2005 Modeled Structures

None of the 2005 modeled structures allowed 100% passage during any of the three migration periods. Passage for adult Chinook was unimpaired less than 33% of the migration period at all of the modeled structures. Passage for adult *O. mykiss* was also poor with unimpaired passage less than about 41% of the migration period at all of the modeled structures. Juvenile passage was unimpaired about 85% of the migration period at Mormon Slough Railroad Bridge and Fine Road Bridge, about 62% of the migration period at Fujinaka Low Flow Road Crossing, and less than 50% of the migration period at Gotelli LFC, Cherryland Flashboard Dam and Lavaggi, and Piazza FBDs.

Riprap was often the feature that had the greatest impact on fish passage at the modeled structures. At Cherryland FBD, Gotelli LFC (RM 6.2), Lavaggi FBD, McAllen Road Bridge and FBD, and Piazza FBD, insufficient depth over riprap significantly impaired fish passage. Shallow channel depths at Fine Road Bridge and Fujinaka LFC impaired fish passage. Insufficient depth in the bridge bays at MSRR Bridge impaired fish passage.

Lavaggi Flashboard Dam

Lavaggi Flashboard Dam is on Mormon Slough near river mile 7.5. The structure consists of a concrete apron and abutments. Riprap scour protection lines the channel bed and banks downstream of the dam. Flashboards can be placed on the concrete apron between the abutments to form a dam. The concrete apron extends approximately 3 feet upstream and 7 feet downstream of the flashboards. The riprap banks and channel bottom extends below the downstream apron into a scour pool (Photo 5-9). Abutments are constructed inside the channel and reduce flow area even without flashboards in place. The site description for Lavaggi FBD is in Appendix A.

Photo 5-9. Lavaggi Flashboard Dam with boards in place

A HEC-RAS model was developed for Lavaggi FBD from cross-section surveys taken upstream and downstream of the structure and from the measurements of the features described above. Manning’s n values ranged from 0.02 on the channel bed and 0.025 on the concrete structure to 0.08 on the vegetated banks and riprap. Model calibration was conducted at three flows: 47 cfs, 220 cfs, and 1980 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the three calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The locations of sections determined to exhibit the worst case passage opportunities are shown in the longitudinal profile in Figure 5-49. The model results of the worst case sections are summarized in the depth and velocity curve graphs in Figures 5-50 and 5-51.

Figure 5-49. Longitudinal profile at Lavaggi FBD

Performance Summary

Phase II fish passage evaluation depth criterion at the dam and over the apron at Lavaggi FBD is 1 foot for adult salmonids. At the dam, this criterion is met at flows of 32 cfs or greater (Figure 5-50). Over the apron, this criterion is met at 35 cfs or greater. The depth criterion over riprap is 2 feet for adult salmonids. The riprap depth criterion is met at 60 cfs or greater. Thus, the depth criterion for unimpaired adult fish passage at Lavaggi FBD is met when flow is 60 cfs or greater.

Figure 5-50. Depth curves for Lavaggi FBD

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At Lavaggi, at flows less than 9 cfs, the velocity must be less than 6 fps (Figure 5-51). As discussed in Chapter 4, as flow increases and depth over the riprap downstream of the apron increases, the allowable velocity also increases. For flows over 9 cfs, the velocity criterion increases to 8 fps. Velocities for all of the structure sections remain below the velocity criterion at all modeled flows. Thus, the velocity criterion is met at all flows.

Figure 5-51. Velocity curves for Lavaggi LFB

Adult salmonid passage is impaired most at riprap where the depth criterion is not met until flow is 60 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Lavaggi FBD. Because adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ. The passage flow ranges for Lavaggi FBD are the ranges defined in Table 4-10 for Mormon Slough, downstream of MSRR Bridge.

Table 5-42 shows adult Chinook passage performance at Lavaggi. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 978 cfs. However, adult Chinook have unimpaired passage at Lavaggi only at 60 cfs and above. From the table, it is apparent that Lavaggi is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 8% of the time during their migration period (Figure 5-52). In the 18 adult Chinook migration seasons in the available period of record that were analyzed for structures on Mormon Slough downstream of MSRR bridge, flows reached or exceeded 600 cfs during 11 of the migration seasons.

Table 5-42. Adult Chinook passage performance at Lavaggi FBD

Figure 5-52. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Lavaggi, Sep through Dec

Table 5-43 shows adult *O. mykiss* passage performance at Lavaggi. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 6 and 4,540 cfs. However, adult *O. mykiss* have unimpaired passage at Lavaggi only at 60 cfs and above. From the table, it is apparent that Lavaggi is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 25% of the time during their migration period (Figure 5-53). In the 18 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 60 cfs during 17 of the migration seasons.

Table 5-43. Adult *O. mykiss* passage performance at Lavaggi FBD

Figure 5-53. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Lavaggi , Oct through Mar

The depth criterion over the dam and in the channel at Lavaggi FBD is 0.5 feet for juvenile salmonids. This criterion is met at the dam at 7 cfs and at the apron at 9 cfs. The depth criterion is met at 25 cfs at riprap (see Figure 5-50). Thus, the depth criterion for unimpaired juvenile fish passage at Lavaggi is met when flow is 25 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles because we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Lavaggi FBD. These lower and upper flows are listed in Table 4-10 for Mormon Slough, downstream of MSRR Bridge. The passage flow range for juveniles is between 1 and 847 cfs. Table 5-44 shows juvenile salmonid passage performance at Lavaggi. Juvenile salmonids have unimpaired passage at Lavaggi only at 25 cfs and above. It is apparent from the table that Lavaggi is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 34% of the time during their

Table 5-44. Juvenile salmonid passage performance at Lavaggi FBD

migration period, as shown in Figure 5-54. In the 18 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 25 cfs during each of the migration seasons.

Figure 5-54. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Lavaggi, Jan through June

Fujinaka Low Flow Road Crossing

The Fujinaka Low Flow Road Crossing is on Mormon Slough near river mile 10.0. The crossing is in the active channel skewed 30 degrees to the flow path (Photo 5-10). The crossing is made of a rough, irregular concrete road prism poured over three reinforced concrete pipes of different sizes, lengths, elevations, and slopes. There is riprap on the bed downstream of the crossing. The site description for Fujinaka LFC is in Appendix A.

Photo 5-10. Fujinaka Low Flow Road Crossing with flow

A HEC-RAS model was developed for Fujinaka LFC from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning's "n" value ranged from 0.015 over the concrete road prism to 0.04 over vegetation. The model was calibrated using a flow of 90 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the calibration flow.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-56 and 5-57. Only the sections where criteria were not met at all modeled flows are shown on the graph. The locations of these sections are shown in the longitudinal profile in Figure 5-55. The results of the phase II fish passage evaluation at Fujinaka are presented below.

Figure 5-55. Longitudinal profile for Fujinaka LFC

Performance Summary

The depth criterion through the culverts and over the road crossing at Fujinaka is 1 foot for adult salmonids. This criterion is met at 22 cfs at channel 1. The depth criterion is met at all modeled flows in culvert 1. The depth criterion is met at 25 cfs and above in culvert 2 and at flows greater than 84 cfs in culvert 3 (Figure 5-56). The depth criterion is met at flows 367 cfs or greater over the road crossing. The depth criterion over riprap at Fujinaka is 2 feet for adult salmonids. The depth criterion is met over the riprap at all flows. Thus, the depth criterion for unimpaired adult fish passage at Fujinaka LFC is met through at least one of the culverts at all modeled flows, over the crossing when flow is 367 cfs or greater, and in the channel at flows of 22 cfs and higher.

Figure 5-56. Depth curves for Fujinaka LFC

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. As mentioned above, the riprap at Fujinaka meets the depth criterion of 2 feet at all modeled flow. Thus, the structure length at Fujinaka is constant and is about 27 feet. The velocity criterion at Fujinaka is 8 fps (Figure 5-57). The velocity criterion is met at all modeled flows at channel and riprap sections. Velocity in culvert 1 exceeds the criterion between 178 and 800 cfs. Likewise, velocity in culvert 2 exceeds the criterion between 181 and 740 cfs. Velocity in culvert 3 meets the criterion at all modeled flows. Velocity over the road crossing is less than the maximum allowable velocity at all flows that overtop the road. Thus, the velocity criterion for unimpaired adult fish passage at Fujinaka is met

Figure 5-57. Velocity curves for Fujinaka LFC

through at least one of the culverts at all modeled flows and over the weir at flows of 300 cfs and above.

Because of the multiple paths available to fish to pass Fujinaka LFC, passage opportunities will be summarized for each path. Adult salmonid passage is impaired in the channel downstream of the culvert when flow is less than 22 cfs. Therefore, adult salmonid passage is unimpaired through culvert 1 for flows between 22 cfs and 178 cfs and for flows greater than 800 cfs. Adult salmonids have unimpaired passage through culvert 2 between 25 and 181 cfs and flows above 740 cfs. Adult salmonids have unimpaired passage through culvert 3 at flows of 84 cfs and higher. Adult salmonids have unimpaired passage over the crossing at flows above 367 cfs. In summary, adult salmonids have unimpaired passage past Fujinaka LFC at flows of 22 cfs and higher. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Fujinaka LFC. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Fujinaka are the ranges defined in Table 4-10 (Fish Passage flow limits in the Calaveras River system) for Mormon Slough downstream of MSRR Bridge.

Table 5-45. Adult Chinook passage performance at Fujinaka LFC

Table 5-45 shows adult Chinook passage performance at Fujinaka. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 978 cfs. However, adult Chinook have unimpaired passage at Fujinaka only at 22 cfs and above. From the table, it is apparent that Fujinaka is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 16% of the time during their migration period (Figure 5-58). In the 18 adult Chinook migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 22 cfs during 16 of the migration seasons.

Figure 5-58. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Fujinaka LFC, Sep through Dec

Table 5-46. Adult *O. mykiss* passage performance at Fujinaka LFC

Table 5-46 shows adult *O. mykiss* passage performance at Fujinaka. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 6 and 4540 cfs. However, adult *O. mykiss* have unimpaired passage at Fujinaka only at 22 cfs and higher. From the table, it is apparent that Fujinaka is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 34% of the time during their migration period (Figure 5-59). In the 18 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR Bridge, flows reached or exceeded 22 cfs during 17 of the migration seasons.

Figure 5-59. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Fujinaka LFC, Oct through Mar

The depth criterion through the culverts and over the road crossing at Fujinaka LFC is 0.5 feet for juvenile salmonids. This criterion is met at 4 cfs at channel 1. The depth criterion is met at all modeled flows in culvert 1, 6 cfs in culvert 2, 45 cfs in culvert 3, and at about 300 cfs over the crossing (Figure 5-60). The depth criterion over riprap at Fujinaka is 1 foot for juvenile salmonids. This criterion is met over the riprap at all modeled flows. Thus, the depth criterion for unimpaired juvenile fish passage at Fujinaka LFC is met when flow is 4 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Figure 5-60. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Fujinaka LFC, Jan through June

Lower and upper passage flows were also determined for juveniles at Fujinaka LFC. These lower and upper flows are listed in Table 4-10 for Mormon Slough downstream of MSRR Bridge. The passage flow range for juveniles is between 1 and 847 cfs. Table 5-47 shows juvenile salmonid passage performance at Fujinaka. Juvenile salmonids have unimpaired passage at Fujinaka only at 4 cfs and above. It is apparent from the table that Fujinaka is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 62% of the time during their migration period, as shown in Figure 5-60. In the 18 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough downstream of MSRR bridge, flows reached or exceeded 4 cfs during 18 of the migration seasons.

Table 5-47. Juvenile salmonid passage performance at Fujinaka Low Flow Road Crossing

Figure 5-60. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Fujinaka LFC, Jan through June

Mormon Slough Railroad Bridge

Mormon Slough Railroad (MSRR) Bridge is on the Mormon Slough near river mile 11. The structure consists of a concrete apron, abutments, and concrete piers supporting a steel railroad bridge deck crossing an earthen channel (Photo 5-11). The railroad bridge crosses the channel at an angle less than 90 degrees relative to the flowline (that is, not perpendicular). Large amounts of riprap line the channel both up and downstream of a concrete apron placed under the structure and around its piers. A large scour/plunge pool has also formed downstream of the apron. Potter Creek adds flow to the channel just below the structure.

Photo 5-11. Mormon Slough Railroad Bridge – Upstream side

A HEC-RAS model was developed for MSRR Bridge from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. The model was also run with a split flow distribution through the bridge to account for the different bed elevations and slopes in each bay. Flows from Potter Creek were also added to the model for calibration. Manning’s n values ranged from 0.012 on the concrete apron to 0.12 on the vegetated sides or riprap sides and banks. The model was calibrated with four flow sets that included a flow for Mormon Slough and a flow for Mormon Slough and Potter creek combined. These flows were 28 and 45 cfs, 161 and 209 cfs, 250 and 280 cfs, and 776 and 1300 cfs, respectively. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles and validated at an estimated flow of 3,000 cfs through the structure.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. Sections that were selected to exhibit the worst case passage scenario are shown in the longitudinal profile in Figure 5-61. The model results of these sections are summarized in the depth and velocity curve graphs in Figures 5-62 and 5-63.

Figure 5-61. Longitudinal profile at MSRR Bridge

Performance Summary

Fish passage evaluation depth criterion at the dam and over the apron at MSRR Bridge is 1 foot for adult salmonids. On the apron this criterion is met at flows 29 cfs or greater (Figure 5-62). Bay 1 of the bridge meets this criterion at 3,060 cfs or greater. This criterion is met at bay 2 at 206 cfs or greater, bay 3 at 32 cfs or greater, bay 4 at 69 cfs or greater, and bay 5 at 2,203 cfs or greater.

Figure 5-62. Depth curves for MSRR Bridge

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At MSRR Bridge, a plunge pool exists down stream of the apron where typical riprap slopes existed on other structures. This results in no riprap slope to be added in the overall length.

The resulting length is the width of the apron, or 53 feet, at all flows. Correspondingly, passable velocities are 6 fps or less (Figure 5-63). Velocities for the apron meet the velocity criterion at or below 802 cfs and at or above 2,857 cfs. Velocity criterion is met at the bridge at bay 1 at all flows, bay 2 from 1,204 cfs and below and from 3,424 cfs and above, and bay 3 from 181 cfs and below and from 3,007 cfs and above. Bay 4 meets the velocity criteria at or below 492 cfs, between 2,942 cfs and 3,744 cfs, and at or above 4,667 cfs, while bay 5 meets the velocity criteria at all flows.

Figure 5-63. Velocity curves for MSRR Bridge

Because of the multiple paths available to fish to pass MSRR Bridge, passage opportunities are summarized for each path. Adult passage is unimpaired on the path through bay 1 when flow is greater than 3,060 cfs. The path through bay 2 is unimpaired between 206 and 802 cfs and above 3,424 cfs. The path through bay 3 is unimpaired between 32 and 181 cfs, and above 3,070 cfs. Adult passage is unimpaired on the path through bay 4 between 69 and 492 cfs, between 2942 and 3,744 cfs, and above 4,667 cfs. The path through bay 5 has unimpaired passage at flows greater than 2,857 cfs. In summary, adults have unimpaired passage past MSRR Bridge between 32 and 802 cfs, and at flows greater than 2,857 cfs.

DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at MSRR Bridge. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for MSRR Bridge are the ranges defined in Table 4-10 for Mormon Slough upstream of MSRR Bridge.

Table 5-48 shows adult Chinook passage performance at MSRR Bridge. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 15 and 1,590 cfs. However, adult Chinook have unimpaired passage at MSRR Bridge only between 32 cfs to 802 cfs. From the table, it is apparent that MSRR Bridge is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 27% of the time during their migration period (Figure 5-64). In the 18 adult Chinook migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 32 cfs during all of the migration seasons.

Table 5-48. Adult Chinook passage performance at MSRR Bridge

Figure 5-64. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at MSRR Bridge, Sep through Dec

Table 5-49 shows adult *O. mykiss* passage performance at MSRR Bridge. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 19 and 5,460 cfs. However, adult *O. mykiss* have unimpaired passage at MSRR Bridge only between 32 cfs to 802 cfs and above 2,857 cfs. From the table, it is apparent that MSRR Bridge is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 30% of the time during their migration period (Figure 5-65). In the 21 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 32 cfs during all of the migration seasons.

Table 5-49. Adult *O. mykiss* passage performance at MSRR Bridge

Figure 5-65. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at MSRR Bridge, Oct through Mar

The depth criterion over the apron and bridge at MSRR Bridge is 0.5 feet for juvenile salmonids. This criterion is met at the apron at 5 cfs, bridge bay 1 at 2,688 cfs, bridge bay 2 at 97.5 cfs, bridge bay 3 at 6 cfs, bridge bay 4 at 24 cfs, and bridge bay 5 at 1,760 cfs (see Figure 5-62). Thus, the depth criterion for unimpaired juvenile fish passage at MSRR Bridge is met when flow is 6 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at MSRR Bridge. These lower and upper flows are listed in Table 4-10 for Mormon Slough upstream of MSRR Bridge. The passage flow range for juveniles is between 1 and 1,248 cfs. Table 5-50 shows juvenile salmonid passage performance at MSRR Bridge. Juvenile salmonids have unimpaired passage at MSRR Bridge only at 6 cfs and above. It is apparent from the table that MSRR Bridge is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 85% of the time during their migration period, as shown in Figure 5-66. In the 21 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 6 cfs during all of the migration seasons.

Table 5-50. Juvenile salmonid passage performance at MSRR Bridge

Figure 5-66. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at MSRR Bridge, Jan through June

Piazza Flashboard Dam

Piazza Flashboard Dam is on Mormon Slough at river mile 12.0. The dam consists of a concrete base between two concrete abutments (Photo 5-12). Riprap lines the channel both upstream and downstream of the dam base. The site description for Piazza FBD is in Appendix A.

Photo 5-12. Piazza Flashboard Dam base at a low flow

A HEC-RAS model was developed for Piazza from cross section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning’s “n” value ranged from 0.04 over the channel to 0.08 over riprap. The model was calibrated using two flows: 70 cfs, and 260 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the two calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-68 and 5-69. Only the sections where criteria were not met at all modeled flows are shown on the graph. The locations of these sections are shown in the longitudinal profile in Figure 5-67. The results of the phase II fish passage evaluation at Piazza are presented below.

Figure 5-67. Longitudinal profile for Piazza FBD

<u>Performance Summary</u>

The depth criterion in the channel and over the dam base at Piazza Dam is 1 foot for adult salmonids. At channel 1, this criterion is met at all modeled flows. The depth criterion is met at 30 cfs at channel 2 and at 100 cfs at channel 3. This criterion is not met until about 75 cfs over the dam base (Figure 5-68). The depth criterion over riprap at Piazza Dam is 2 feet for adult salmonids. At riprap 1 this criterion is met at 114 cfs or greater, while at riprap 2 this criterion is met at flows greater than 330 cfs. Flow is 2 feet deep at riprap 3 when flows exceed 150 cfs. Thus, the depth criterion for unimpaired adult fish passage at Piazza Dam is met when flow is 330 cfs or greater.

Figure 5-68. Depth curves for Piazza FBD

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At flows less than 17 cfs, the velocity must be less than 5 fps (Figure 5-69). As flow increases and depth over the riprap downstream of the dam increases, the allowable velocity also

Figure 5-69. Velocity curves for Piazza FBD

increases. Between 17 and 123 cfs, the maximum velocity allowed for unimpaired fish passage is 6 fps. Between 123 and 265 cfs, the maximum velocity allowed for unimpaired fish passage is 8 fps, and at flows greater than 265 cfs, the velocity criterion increases to 10 fps. Velocity at the channel sections meets the velocity criterion at all modeled flows. Velocity over the dam base meets the velocity criterion at all modeled flows. Velocity over the riprap sections also meets the velocity criterion at all modeled flows. Thus the velocity criterion is met at all modeled flows.

Adult salmonid passage is impaired most at riprap 2 where the depth criterion is not met until flow is 330 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Piazza FBD. Because adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Piazza FBD are the ranges defined in Table 4-10 for Mormon Slough upstream of MSRR Bridge.

Table 5-51 shows adult Chinook passage performance at Piazza. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 15 and 1,590 cfs. However, adult Chinook have unimpaired passage at Piazza only at 330 cfs and above. From the table, it is apparent that Piazza is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 6% of the time during their migration period (Figure 5-70). In the 18 adult Chinook migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 330 cfs during 10 of the migration seasons.

Table 5-51. Adult Chinook passage performance at Piazza FBD

Figure 5-70. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Piazza, Sep through Dec

Table 5-52 shows adult *O. mykiss* passage performance at Piazza. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 19 and 5460 cfs. However, adult *O. mykiss* have unimpaired passage at Piazza only at flows of 330 cfs and greater. From the table, it is apparent that Piazza is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 17% of the time during their migration period (Figure 5-71). In the 21 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 330 cfs during 20 of the migration seasons.

Table 5-52. Adult *O. mykiss* passage performance at Piazza FBD

Figure 5-71. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Piazza, Oct through Apr

The depth criterion in the channel and over the dam base at Piazza FBD is 0.5 feet for juvenile salmonids. This criterion is met at all modeled flows at channel 2. The depth criterion is met at about 3 cfs at channel 1 and at 10 cfs at channel 3. This criterion is not met until 25 cfs over the dam base (see Figure 5-68). The depth criterion over riprap at Piazza Dam is 1 foot for juvenile salmonids. At riprap 1, this criterion is met at 10 cfs or greater, while at riprap 2 this criterion is met at flows greater than 170 cfs. Flow is 1 foot deep at riprap 3 when flows exceed 15 cfs. Thus, the depth criterion for unimpaired juvenile fish passage at Piazza FBD is met when flow is 170 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Piazza Dam. These lower and upper flows are listed in Table 4-10 for Stockton Diverting Canal. The passage flow range for juveniles is between 1 cfs and

1,248 cfs. Table 5-53 shows juvenile salmonid passage performance at Piazza. Juvenile salmonids have unimpaired passage at Piazza only at 170 cfs and higher. It is apparent from the table that Piazza is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 22% of the time during their migration period, as shown in Figure 5-72. In the 21 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 170 cfs during 20 of the migration seasons.

Table 5-53. Juvenile salmonid passage performance at Piazza FBD

Figure 5-72. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Piazza, Jan through June

Fine Road Bridge

Fine Road Bridge is a concrete and steel structure 206 feet long across Mormon Slough at river mile 15.4. The structure is supported by two concrete piers 65 feet apart. The piers stand at the edges of the active channel (Photo 5-13). Although the active channel measures 65 feet wide below the bridge, it narrows to about 50 feet upstream and downstream of the bridge. The channel upstream and downstream of the bridge is straight. The banks are steep, and for the most part, covered with riprap and grass and shrubs. The site description for Fine Road Bridge is in Appendix A.

Photo 5-13. Fine Road Bridge

A HEC-RAS model was developed for Fine Road Bridge using cross section surveys upstream and downstream of the structure and from the measurements of the bridge. Manning's n values ranged from 0.03 on the channel bottom to 0.07 on the vegetated banks.

The model was calibrated using two flows: 92 cfs, and 270 cfs. The model was adjusted such that the calculated water surface profiles matched closely with the measured water surface profiles from the two calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figure 5-74 and 5-75. Only the sections where criteria were not met at all modeled flows are shown on the graph. The locations of these sections are shown in the longitudinal profile in Figure 5-73. The results of the Phase II fish passage evaluation at Fine Road Bridge are presented below.

Figure 5-73. Longitudinal profile for Fine Road Bridge

Performance Summary

The depth criterion at the bridge and in the channel at Fine Road Bridge is 1 foot for adult salmonids. At section channel 1, this criterion is met at flows 28 cfs or greater (Figure 5-74). At section channel 2, this criterion is met at all modeled flows. Thus, the depth criterion for unimpaired adult fish passage at Fine Road Bridge is met when flow is 28 cfs or greater.

Figure 5-74. Depth curves for Fine Road Bridge

The velocity criterion for adult salmonids at Fine Road Bridge is 6 fps (Figure 5-75). Velocity at the section Channel 1, the velocity criterion at all modeled flows. At section Channel 2, the velocity criterion is met when flows are less than 3,750 cfs. Thus, the velocity criterion for unimpaired fish passage at Fine Road Bridge is met when flow is less than 3,750 cfs.

Figure 5-75. Velocity curves for Fine Road Bridge

Adult salmonid passage at Fine Road Bridge is impaired below 28 cfs because of insufficient flow depth at channel 1 and above 3,750 cfs when the velocity criterion is exceeded at channel 2. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Fine Road Bridge. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Fine Road Bridge are the ranges defined in Table 4-10 for Mormon Slough upstream of MSRR Bridge.

Table 5-54 shows adult Chinook passage performance at Fine Road Bridge. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 15 and 1,590 cfs. However, adult Chinook have unimpaired passage at Fine Road Bridge only between 26 cfs and 3,750 cfs. From the table, it is apparent that the river channel at Fine Road Bridge is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 33% of the time during their migration period (Figure 5-76). In the 18 adult Chinook migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 28 cfs during all of the migration seasons.

Table 5-54. Adult Chinook passage performance at Fine Road Bridge

Figure 5-76. Mormon Slough upstream of MSRR Crossing flow duration curve showing adult Chinook passage performance at Fine Road Bridge, Sep through Dec

Table 5-55 shows adult *O. mykiss* passage performance at Fine Road Bridge. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 19 and 5,460 cfs. However, adult *O. mykiss* have unimpaired passage at Fine Road Bridge only between 28 cfs and 3,750 cfs. From the table, it is apparent that the river channel at Fine Road Bridge is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 41% of the time during their migration period (Figure 5-77). In the 21 adult *O. mykiss* migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Bridge, flows reached or exceeded 28 cfs during all of the migration seasons.

Table 5-55. Adult *O. mykiss* passage performance at Fine Road Bridge

Figure 5-77. Mormon Slough upstream of MSRR Crossing flow duration curve showing adult *O. mykiss* passage performance at Fine Road Bridge, Oct through Mar

The depth criterion at the bridge and in the channel at Fine Road Bridge is 0.5 feet for juvenile salmonids. The depth criterion is met at 7.5 cfs at channel 1 (see Figure 5-74). This criterion is met for all flows at channel 2. Thus, the depth criterion for unimpaired juvenile fish passage at Fine Road Bridge is met when flow is 7.5 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles because we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Fine Road Bridge. These lower and upper flows are listed in Table 4-10 for Mormon Slough upstream of MSRR Crossing. The passage flow range for juveniles is between 1 and 1,248 cfs. Table 5-56 shows juvenile salmonid passage performance at Fine Road Bridge. Juvenile salmonids have unimpaired passage at Fine Road Bridge only when flow is 7.5 cfs or higher. It is apparent from the table that the river channel at Fine Road Bridge is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 85% of the time during their migration period, as shown in Figure 5-78. In the 21 juvenile salmonid migration seasons that were analyzed for structures on Mormon Slough upstream of MSRR Crossing, flows reached or exceeded 7.5 cfs during all of the migration seasons.

Table 5-56. Juvenile salmonid passage performance at Fine Road Bridge

Figure 5-78. Mormon Slough upstream of MSRR Crossing flow duration curve showing juvenile salmonid passage performance at Fine Road Bridge, Jan through June

Gotelli Low Flow Road Crossing

Gotelli Low Flow Road Crossing is on the Calaveras River at river mile 6.2, just upstream of the confluence with Stockton Diverting Canal. The structure consists of an earthen filled crossing over a corrugated metal culvert placed in the channel. The channel and banks are protected with riprap immediately downstream of the structure. The channel is additionally constricted through an abandoned bridge crossing downstream from the structure (Photo 5-14).

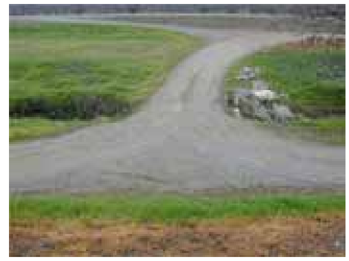


Photo 5-14. Gotelli Low Flow Road Crossing

A HEC-RAS model was developed for Gotelli LFC from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning's n values ranged from 0.025 on bare earth and gravel surfaces to 0.1 on the riprap. Due to an absence of flow profile data to calibrate the model, boundary conditions were taken from similar structures on this reach of the Calaveras River.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. Sections that were selected to exhibit the worst case passage scenario are shown in the longitudinal profile in Figure 5-79. The model results of these sections are summarized in the depth and velocity curve graphs in Figures 5-80 and 5-81.

Figure 5-79. Longitudinal profile at Gotelli Low LFC

Performance Summary

Hydraulic characteristics of the structure were such that the culvert solely conveyed flows up to 60 cfs at which point flow will overtop the crossing, creating two different paths for fish passage. The depth criterion at the crossing and in the culvert at Gotelli LFC is 1 foot for adult salmonids. Over the crossing, this criterion is met at flows 98 cfs or greater (Figure 5-80). Through the culvert, this criterion is met at all modeled flows. The depth criterion over riprap at Gotelli is 2 feet for adult salmonids. Depth criterion for riprap is met at 34 cfs or greater. Thus, the depth criterion for unimpaired adult fish passage at Gotelli LFC is met when flow exceeds 34 cfs for the culvert and 98 cfs for the crossing.

Figure 5-80. Depth curves for Gotelli LFC

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At Gotelli, maximum velocities are 10 fps and 8 fps (Figure 5-81) for the crossing and culvert respectively. Velocities in the culvert, over the crossing, and over the riprap were less than the velocity criterion at all modeled flows.

Figure 5-81. Velocity curves for Gotelli LFC

Adult salmonid passage Gotelli LFC is impaired most over the riprap downstream of the culvert where the depth criterion is not met until flow is greater than 34 cfs. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Gotelli LFC. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Gotelli LFC are the ranges defined in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal.

Table 5-57 shows adult Chinook passage performance at Gotelli. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 97 cfs. However, adult Chinook have unimpaired passage at Gotelli only at 34 cfs and above. From the table, it is apparent that Gotelli is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 4% of the time during their

Table 5-57. Adult Chinook passage performance at Gotelli LFC

migration period (Figure 5-82). In the 21 adult Chinook migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 34 cfs during 13 of the migration seasons.

Figure 5-82. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at Gotelli, Sep through Dec

Table 5-58 shows adult *O. mykiss* passage performance at Gotelli. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 3 and 166 cfs. However, adult *O. mykiss* have unimpaired passage at Gotelli only at 34 cfs and above. From the table, it is apparent that Gotelli is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 9% of the time during their migration period (Figure 5-83). In the 22 adult *O. mykiss* migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 34 cfs during 17 of the migration seasons.

Table 5-58. Adult *O.mykiss* passage performance at Gotelli LFC

Figure 5-83. Calaveras River Headworks to SDC flow duration curve showing adult O.mykiss passage performance at Gotelli, Oct through Mar

The depth criterion over the crossing and through the culvert at Gotelli LFC is 0.5 feet for juvenile salmonids. This criterion is met over the crossing at 72 cfs and through the culvert for all flows. Depth criterion over riprap at Gotelli is 1 feet for juvenile salmonids. The depth criterion is met at 10.5 cfs at riprap (see Figure 5-80). Thus, the depth criterion for unimpaired juvenile fish passage at Gotelli LFC is met when flow over the riprap is 10.5 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Gotelli LFC. These lower and upper flows are listed in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal. The passage flow range for juveniles is between 1 and 38 cfs. Table 5-59 shows juvenile salmonid passage performance at Gotelli. Juvenile salmonids have unimpaired passage at Gotelli only at 10.5 cfs and above. It is apparent from the table that Gotelli is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 48% of the time during their migration period, as shown in Figure 5-84. In the 21 juvenile salmonid migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 10.5 cfs during all of the migration seasons.

Table 5-59. Juvenile salmonid passage performance at Gotelli LFC

Figure 5-84. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Gotelli, Jan through June

McAllen Road Bridge

McAllen Road Bridge is on the Calaveras River near river mile 6. The structure consists of a paved road bridge supported with cylindrical piers spanning a riprap lined channel. McAllen Flashboard Dam is immediately upstream of the bridge where a concrete apron makes a hardpoint in the channel bed. The riprap slope extends downstream from the dam apron, through the bridge piers and extends downstream of the bridge approximately 140 feet (Photo 5-15).

Photo 5-15. McAllen Road Bridge from the upstream side

A HEC-RAS model was developed for McAllen Road Bridge from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning’s n values ranged from 0.015 on the concrete apron and sand bed sections to 0.12 on the vegetated banks and riprap. The model was calibrated with two flows: 12 cfs and 25 cfs. Calculated water surface profiles were matched closely with the measured water surface profiles by adjusting the model.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-86 and 5-87. Only the worst case sections of each structure component are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-85. The results of the Phase II fish passage evaluation at McAllen Road Bridge are presented below.

Figure 5-85. Longitudinal profile at McAllen Road Bridge

Performance Summary

The depth criterion over riprap at McAllen Road Bridge is 2 feet for adult salmonids. The depth criterion for riprap under the bridge is met at 37 cfs or greater while the depth criterion on riprap elsewhere is met at 40 cfs or greater (Figure 5-86). Thus, the depth criterion for unimpaired adult fish passage at McAllen Road Bridge is met when flow is 40 cfs or greater.

Figure 5-86. Depth curves for McAllen Road Bridge

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At McAllen, at flows less than 27 cfs, the velocity must be less than 4 fps (Figure 5-87). As discussed in Chapter 4, as flow increases and depth over the riprap downstream of the apron increases, the allowable velocity also increases. Between 27 and 29 cfs, the velocity criterion increases to 5 fps and between 29 and 36 cfs, the velocity criterion increases to 6 fps. For flows greater than 36 cfs the velocity criterion increases to 8 fps. Velocities through the bridge, and over the riprap meet the velocity criterion at all modeled flows.

Figure 5-87. Velocity curves for McAllen Road Bridge

Adult salmonid passage is impaired most at riprap where the depth criterion is not met until flow is 40 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at McAllen Road Bridge. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for McAllen Road Bridge are the ranges defined in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal.

Table 5-60. Adult Chinook passage performance at McAllen Road Bridge

Table 5-60 shows adult Chinook passage performance at McAllen. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 97 cfs. However, adult Chinook have unimpaired passage at McAllen only at 40 cfs and above. From the table, it is apparent that McAllen is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 3% of the time during their migration period (Figure 5-88). In the 21 adult Chinook migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 40 cfs during 7 of the migration seasons.

Figure 5-88. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at McAllen Road Bridge, Sep through Dec

Table 5-61. Adult *O. mykiss* passage performance at McAllen Road Bridge

Table 5-61 shows adult *O. mykiss* passage performance at McAllen Road Bridge. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 3 and 166 cfs. However, adult *O. mykiss* have unimpaired passage at McAllen only at 40 cfs and above. From the table, it is apparent that McAllen is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 7% of the time during their migration period (Figure 5-89). In the 22 adult *O. mykiss* migration seasons that were analyzed for structures on the Calaveras River

Figure 5-89. Calaveras River Headworks to SDC flow duration curve showing adult *O. mykiss* passage performance at McAllen Road Bridge, Oct through Mar

between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 40 cfs during 15 of the migration seasons.

The depth criterion over riprap at McAllen Road Bridge is 1 foot for juvenile salmonids. This depth criterion is met at 8 cfs on bridge riprap and other riprap at 9 cfs (see Figure 5-86). Thus, the depth criterion for unimpaired juvenile fish passage at McAllen is met when flow is 9 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at McAllen Road Bridge. These lower and upper flows are listed in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal. The passage flow range for juveniles is between 1 and 38 cfs. Table 5-62 shows juvenile salmonid passage performance at McAllen. Juvenile salmonids have unimpaired passage at McAllen Road Bridge only at 9 cfs and above. It is apparent from the table that McAllen is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 51% of the time during their migration period, as shown in Figure 5-90. In the 21 juvenile salmonid migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 9 cfs during all of the migration seasons.

Table 5-62. Juvenile salmonid passage performance at McAllen Road Bridge

Figure 5-90. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at McAllen Road Bridge, Jan through June

McAllen Flashboard Dam

McAllen Flashboard Dam is on the Calaveras River near river mile 6, immediately upstream of the McAllen Road Bridge. The structure consists of a roughly cast concrete apron located within a riprap lined channel. Flashboards can be placed on the concrete apron to form a dam. The riprap slope extends downstream through the bridge piers. (Photo 5-16). Cemented riprap lines the channel upstream of the concrete apron. The cemented riprap provides scour protection for four drainage culvert outlets from a nearby development. Loose riprap lines the channel downstream from the concrete apron, under the bridge and downstream to approximately 160 feet from the apron (Figure 5-91).

Photo 5-16. McAllen Flashboard Dam without boards in place

A HEC-RAS model was developed for McAllen FBD from cross-section surveys upstream and downstream of the structure and from the measurements of the features described above. Manning’s n values ranged from 0.015 on the concrete apron and sand bed sections to 0.12 on the vegetated banks and riprap. The model was calibrated with two flows: 12 cfs and 25 cfs. Calculated water surface profiles were matched closely with the measured water surface profiles by adjusting the model.

Figure 5-91. Longitudinal profile at McAllen FBD

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4. The model results are summarized in the depth and velocity curve graphs in Figures 5-92 and 5-93. Only the worst case sections of each structure component are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-91. The results of the Phase II fish passage evaluation at McAllen are presented below.

Performance Summary

The depth criterion at the dam and over the apron at McAllen FBD is 1 foot for adult salmonids. At the dam, this criterion is met at flows 27 cfs or greater (Figure 5-92). Over the apron, this criterion is met at 27 cfs or greater. The depth criterion over riprap at McAllen is 2 feet for adult salmonids. The depth criterion for riprap under the bridge is met at 37 cfs or greater while the depth criterion on riprap elsewhere is met at 40 cfs or greater. Thus, the depth criterion for unimpaired adult fish passage at McAllen FBD is met when flow is 40 cfs or greater.

Figure 5-92. Depth curves for McAllen FBD

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length changes as riprap becomes inundated with 2 feet of water or more. At McAllen FBD, at flows up to 28 cfs, the velocity must be 4 fps or less (Figure 5-93). As flow increases and depth over the riprap downstream of the apron increases, the allowable velocity also increases (see Chapter 4). Between 28 and 37 cfs, the velocity criterion increases to 5 fps, between 37 and 43 cfs, the velocity criterion increases to 6 fps and between 43 and 47 cfs, the velocity criterion increases to 8 fps. For flows greater than 47 cfs the velocity criterion increases to 10 fps. Velocities over the dam base, on the apron, through the bridge, and over the riprap meet the velocity criterion at all modeled flows.

Figure 5-93. Velocity curves for McAllen FBD

Adult salmonid passage is impaired most at riprap where the depth criterion is not met until flow is 40 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at McAllen FBD. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for McAllen FBD are the ranges defined in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal.

Table 5-63 shows adult Chinook passage performance at McAllen FBD. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 97 cfs. However, adult Chinook have unimpaired passage at McAllen FBD only at 40 cfs and above. From the table, it is apparent that McAllen FBD is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 3% of the time during their migration period (Figure 5-94). In the 21 adult Chinook migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 40 cfs during 7 of the migration seasons.

Table 5-63. Adult Chinook passage performance at McAllen FBD

Figure 5-94. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at McAllen FBD, Sep through Dec

Table 5-64 shows adult *O. mykiss* passage performance at McAllen FBD. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 3 and 166 cfs. However, adult *O. mykiss* have unimpaired passage at McAllen only at 40 cfs and above. From the table, it is apparent that McAllen FBD is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 7% of the time during their migration period (Figure 5-95). In the 22 adult *O. mykiss* migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 40 cfs during 15 of the migration seasons.

Table 5-64. Adult *O. mykiss* passage performance at McAllen FBD

Figure 5-95. Calaveras River Headworks to SDC flow duration curve showing adult *O. mykiss* passage performance at McAllen FBD, Oct through Mar

The depth criterion over the dam and in the channel at McAllen FBD is 0.5 feet for juvenile salmonids. This criterion is met at the dam and apron at 13 cfs. Depth criterion over riprap at flashboard dam is 1 foot for juvenile salmonids. The depth criterion is met at 8 cfs at bridge riprap and other riprap at 9 cfs (see Figure 5-92). Thus, the depth criterion for unimpaired juvenile fish passage at McAllen FBD is met when flow is 13 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at McAllen FBD. These lower and upper flows are listed in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal. The passage flow range for juveniles is between 1 and 38 cfs. Table 5-65 shows juvenile salmonid passage performance at McAllen FBD. Juvenile salmonids have unimpaired passage at McAllen only at 13 cfs and above. It is apparent from the table that McAllen is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 43% of the time during their migration period, as shown in Figure 5-96. In the 21 juvenile salmonid migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 13 cfs during all of the migration seasons.

Table 5-65. Juvenile salmonid passage performance at McAllen FBD

Figure 5-96. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at McAllen FBD, Jan through June

Cherryland Flashboard Dam

Cherryland Flashboard Dam is on the Calaveras River near river mile 7.5. The structure consists of concrete lined channel with a flashboard dam placed near the upper end of the lining (Photo 5-17). The lining encompasses the channel, roughly from top of bank to top of bank and continues downstream for approximately 20 feet, where the lining invert changes into riprap over the next 15 feet down stream. Below the structure, the channel is covered with large pieces of concrete riprap (Figure 5-97).

Photo 5-17. Cherryland Flashboard Dam without boards in place

A HEC-RAS model was developed for Cherryland FBD from cross-section surveys of the structure and the channel upstream and downstream. Manning's n values ranged from 0.02 at the structure to 0.1 on the vegetated banks. The model was calibrated with two flows: 12 cfs and 25 cfs. Calculated water surface profiles from the model were adjusted to match closely with the measured water surface profiles from the two calibration flows.

The HEC-RAS model was run under a wide range of flows and results were compared with depth and velocity criteria identified in Chapter 4 of the previous report. The model results are summarized in the depth and velocity curve graphs in Figures 5-98 and 5-99. Only the sections where criteria were not met at all modeled flows are shown on the graphs. The locations of these sections are shown in the longitudinal profile in Figure 5-97. The results of the phase II fish passage evaluation at Cherryland are presented below.

Figure 5-97. Longitudinal profile at Cherryland FBD

Performance Summary

The depth criterion at the crossing and over the apron at Cherryland FBD is 1 foot for adult salmonids. At the dam, this criterion is met at flows 30 cfs or greater (Figure 5-98). Over the apron, this criterion is met at 40 cfs or greater. The depth criterion over riprap at Cherryland is 2 feet for adult salmonids. At riprap 1 this criterion is met at 6 cfs or greater, while at riprap 2 this criterion is met at flows greater than 62 cfs. The depth criterion is met at riprap 3 at 44 cfs, and at riprap 4 at 42 cfs. Thus, the depth criterion for

Figure 5-98. Depth curves for Cherryland FBD

unimpaired adult fish passage at Cherryland FBD is met when flow is 62 cfs or greater.

As discussed in Chapter 4, the velocity criterion for adult passage is dependent on structure length. Structure length is measured from the top of the structure to the point at which riprap becomes inundated with 2 feet of water or more. At Cherryland, for flows less than 34 cfs, the velocity must be less than 4 fps (Figure 5-99). As flow increases and depth over the riprap downstream of the apron increases, the allowable velocity also increases (see Chapter 4). Between 34 and 40 cfs, the velocity criterion increases to 5 fps and between 40 and 50 cfs, the velocity criterion increases to 6 fps. For flows greater than 50 cfs the velocity criterion increases to 8 fps. Velocity at the apron meets the 4 fps criterion up to 18 cfs and, the 5 fps criterion starting at 34 cfs up to 38 cfs and the 6 fps criterion at 40 cfs and higher. Riprap 2 meets the velocity criterion up to 22 cfs and from 26 cfs up. Velocities for the dam, riprap 1, riprap 3, and riprap 4 sections meet the velocity criterion at all modeled flows. Thus the velocity criterion is met at flows up to 18 cfs, between 34 and 38 cfs inclusive, and at flows equal or greater than 40 cfs.

Figure 5-99. Velocity curves for Cherryland FBD

Adult salmonid passage is impaired most at riprap 2 where the depth criterion is not met until flow is 62 cfs or greater. DFG (2002) guidelines were used to determine lower and upper passage flows for adult Chinook and *O. mykiss* at Cherryland FBD. Since adult Chinook and *O. mykiss* have different migration seasons, their passage flow ranges differ from each other. The passage flow ranges for Cherryland FBD are the ranges defined in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal.

Table 5-66 shows adult Chinook passage performance at Cherryland. According to the DFG exceedance flow criteria, adult Chinook should have unimpaired passage between 3 and 97 cfs. However, adult Chinook have unimpaired passage at Cherryland only at 62 cfs and above. From the table, it is apparent that Clements is a temporal barrier to adult Chinook passage. Adult Chinook have unimpaired passage at this structure about 2% of the time during their migration period (Figure 5-100). In the 21 adult Chinook migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 62 cfs during 4 of the migration seasons.

Table 5-66. Adult Chinook passage performance at Cherryland FBD

Figure 5-100. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at Cherryland FBD, Sep through Dec

Table 5-67 shows adult *O. mykiss* passage performance at Cherryland. According to the DFG exceedance flow criteria, adult *O. mykiss* should have unimpaired passage between 3 and 166 cfs. However, adult *O. mykiss* have unimpaired passage at Cherryland only at 62 cfs and above. From the table, it is apparent that Cherryland is a temporal barrier to adult *O. mykiss* passage. Adult *O. mykiss* have unimpaired passage about 5% of the time during their migration period (Figure 5-101). In the 22 adult *O. mykiss* migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 62 cfs during 15 of the migration seasons.

Table 5-67. Adult *O. mykiss* passage performance at Cherryland FBD

Figure 5-101. Calaveras River Headworks to SDC flow duration curve showing adult *O. mykiss* passage performance at Cherryland FBD, Oct through Mar

The depth criterion over the dam and in the channel at Cherryland FBD is 0.5 feet for juvenile salmonids. This criterion is met at the dam at 8 cfs and apron at 13 cfs. The depth criterion is met at all flows at riprap 1, at 6 cfs at riprap 2, at 2 cfs at riprap 3, and at 13 cfs at riprap 4 (see Figure 5-98). Thus, the depth criterion for unimpaired juvenile fish passage at Cherryland is met when flow is 13 cfs or greater. As discussed in Chapter 4, velocity criteria were not considered for juveniles since we are only concerned with their downstream migration.

Lower and upper passage flows were also determined for juveniles at Cherryland FBD. These lower and upper flows are listed in Table 4-10 for Calaveras River, Calaveras Headworks downstream to Stockton Diverting Canal. The passage flow range for juveniles is between 1 and 38 cfs. Table 5-68 shows juvenile salmonid passage performance at Cherryland. Juvenile salmonids have unimpaired passage at Cherryland only at 13 cfs and above. It is apparent from the table that Cherryland is a temporal barrier to juvenile salmonid passage. Juveniles have unimpaired passage past the structure about 42% of the time during their migration period, as shown in Figure 5-102. In the 21 juvenile salmonid migration seasons that were analyzed for structures on the Calaveras River between the Headworks and the Stockton Diverting Canal, flows reached or exceeded 13 cfs during all of the migration seasons.

Table 5-68. Juvenile salmonid passage performance at Cherryland FBD

Figure 5-102. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Cherryland FBD, Jan through June

Chapter 5 Fish Passage Evaluation Results

List of Figures

Figure 5-1. Longitudinal profile for Central California Traction Railroad Bridge

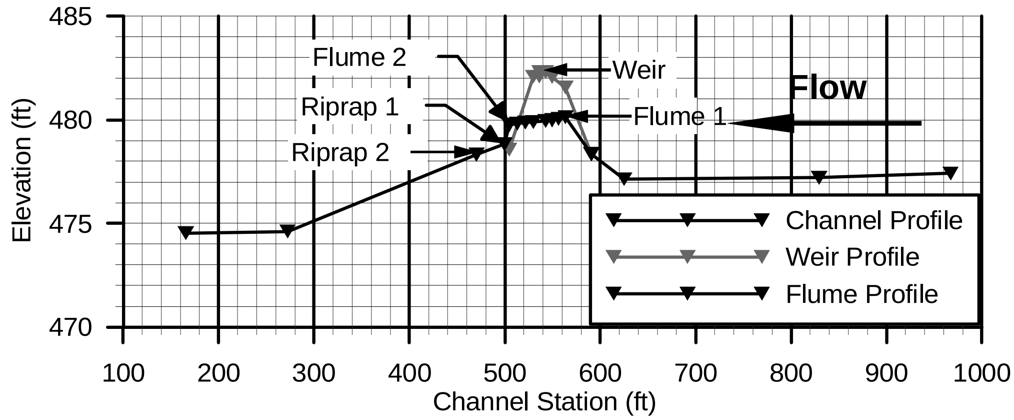


Figure 5-2. Depth curves for Central California Traction Railroad Bridge

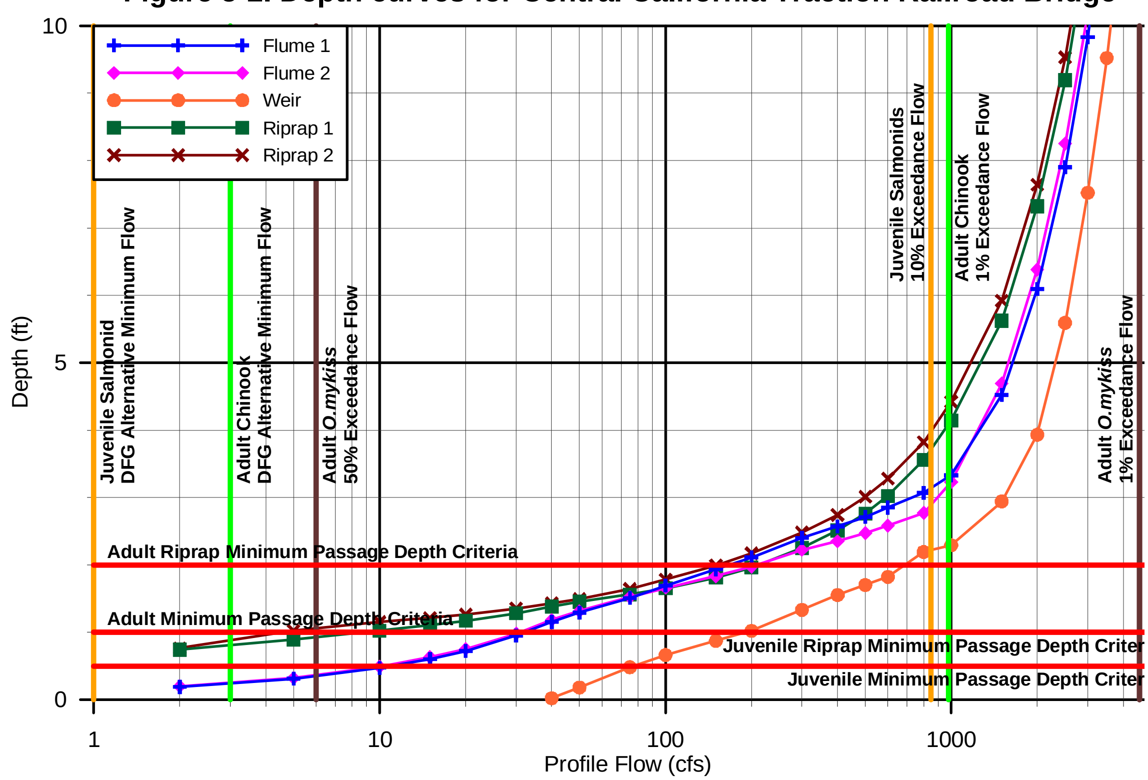


Figure 5-3. Velocity curves for Central California Traction Railroad Bridge

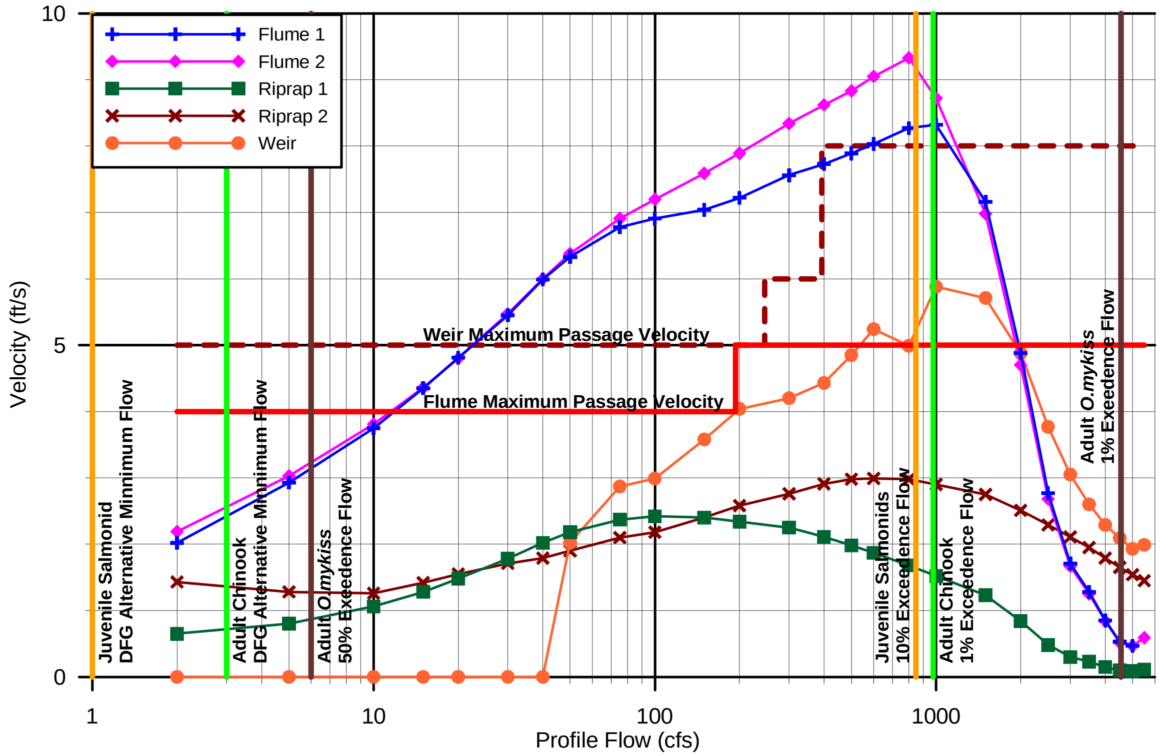


Figure 5-4. Stockton Diverting Canal flow duration curve showing adult Chinook passage performance at CCTRR, Sep through Dec

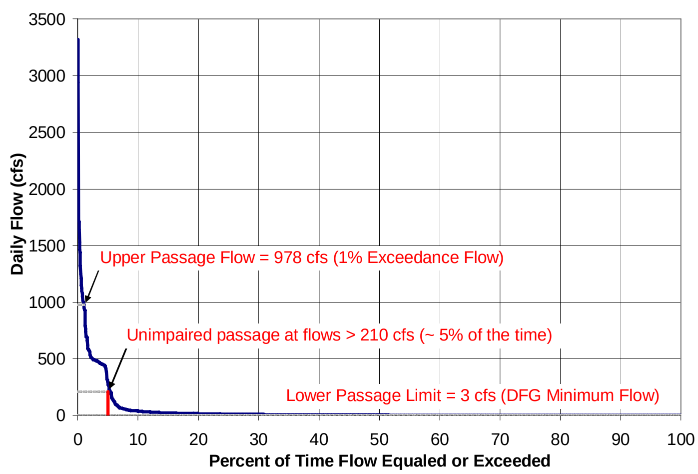


Figure 5-5. Stockton Diverting Canal flow duration curve showing adult *O. mykiss* passage performance at CCTRR, Oct through Mar

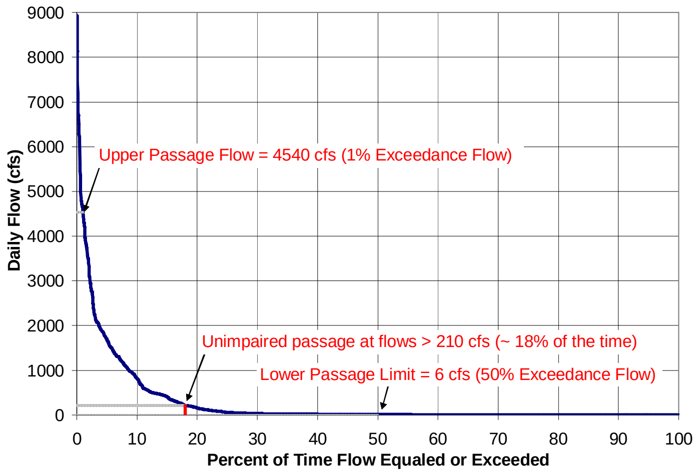


Figure 5-6. Stockton Diverting Canal flow duration curve showing juvenile salmonid passage performance at CCTRR, Jan through June

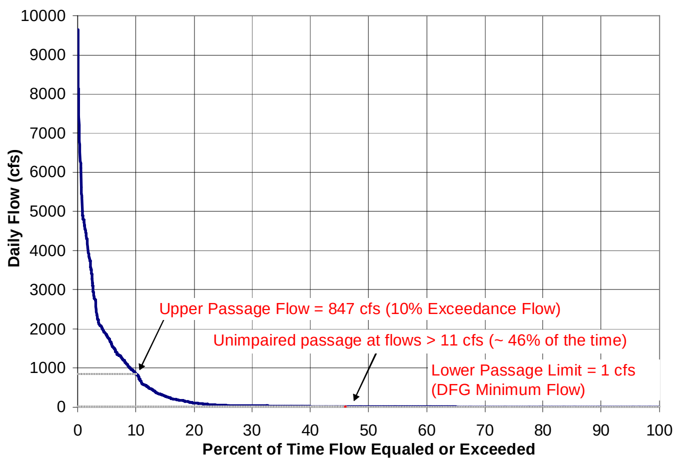


Figure 5-7. Longitudinal profile for Budiselich Flashboard Dam

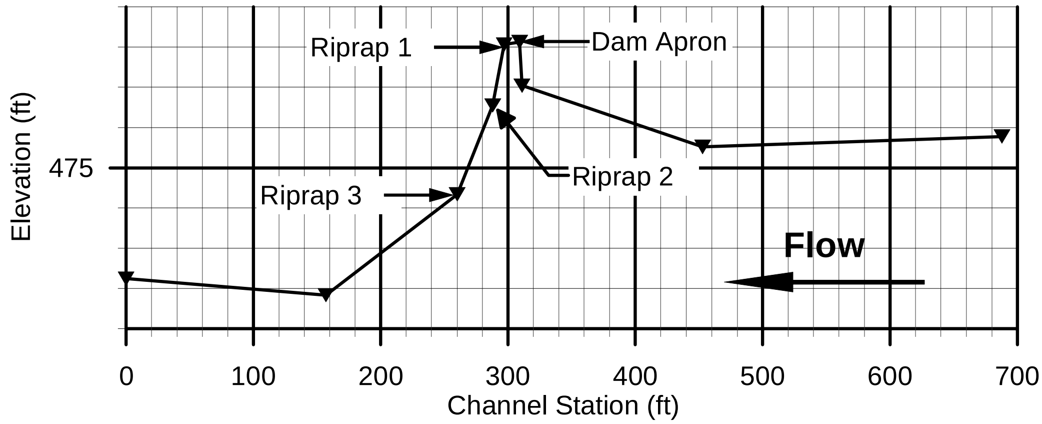


Figure 5-8. Depth curves for Budiselich Flashboard Dam

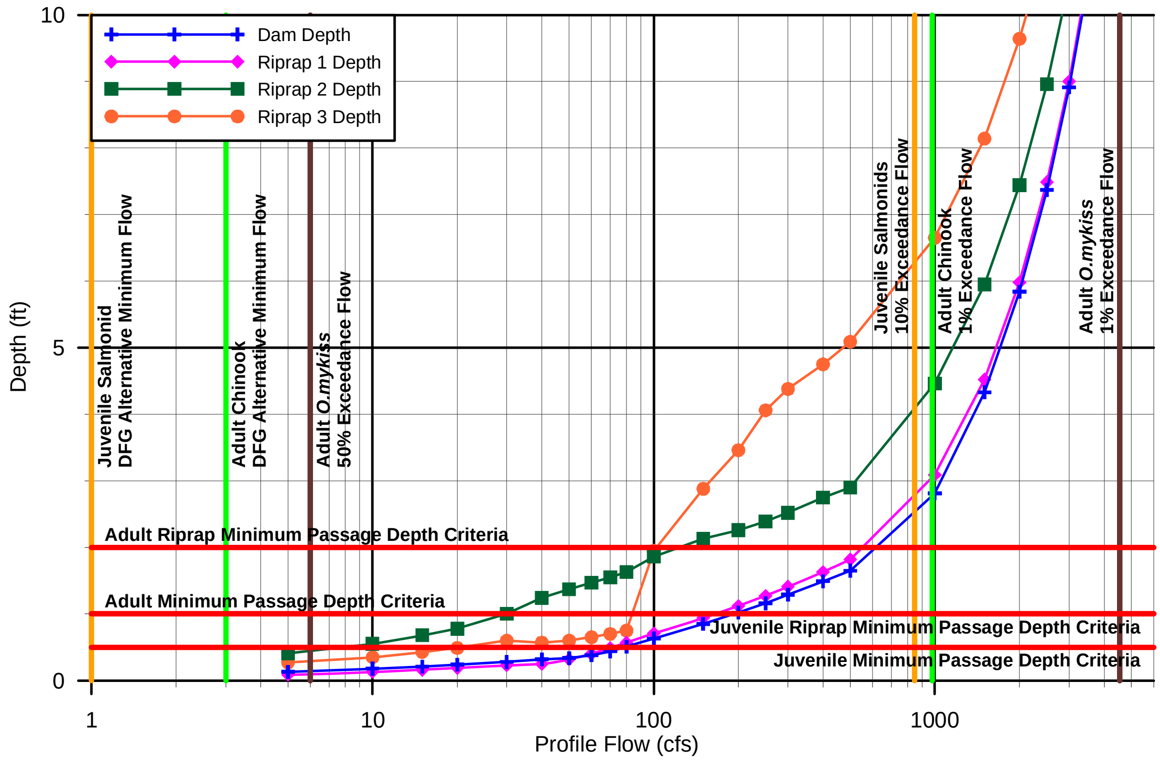


Figure 5-9. Velocity curves for Budiselich Flashboard Dam

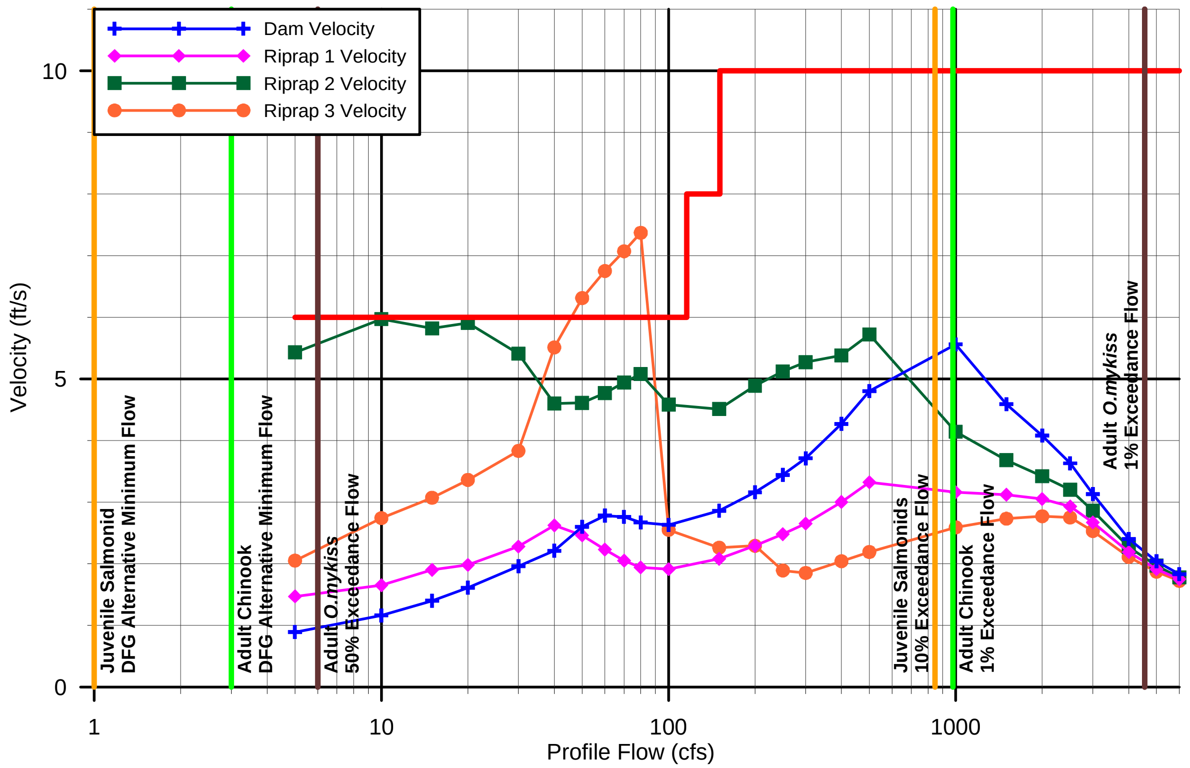


Figure 5-10. Stockton Diverting Canal flow duration curve showing adult Chinook passage performance at Budiselich FBD, Sep through Dec

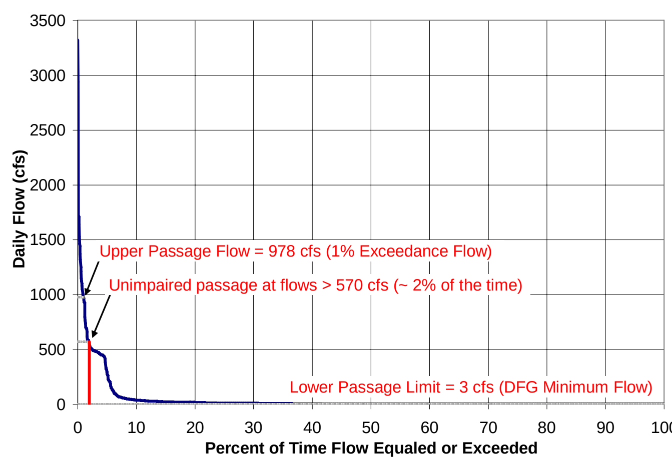


Figure 5-11. Stockton Diverting Canal flow duration curve showing adult *O. mykiss* passage performance at Budiselich FBD, Oct through Mar

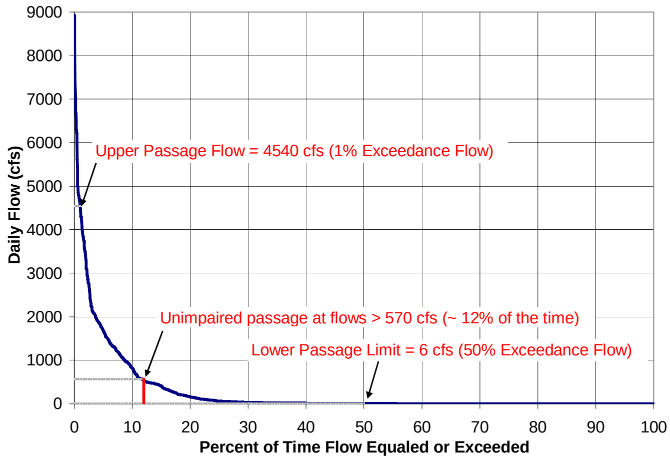


Figure 5-12. Stockton Diverting Canal flow duration curve showing juvenile salmonid passage performance at Budiselich FBD, Jan through June

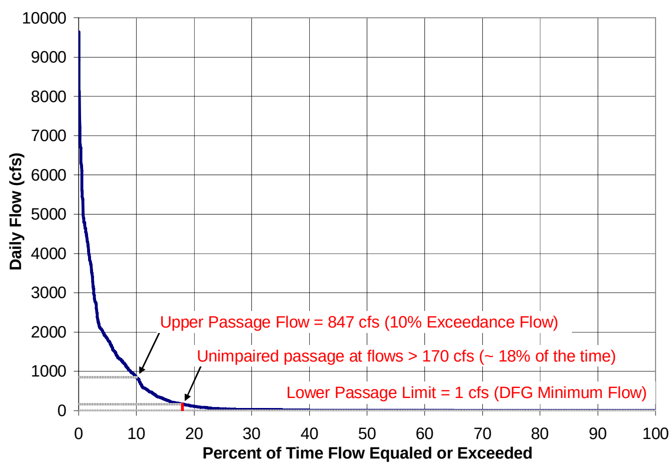


Figure 5-13. Longitudinal profile for Caprini Low Flow Road Crossing

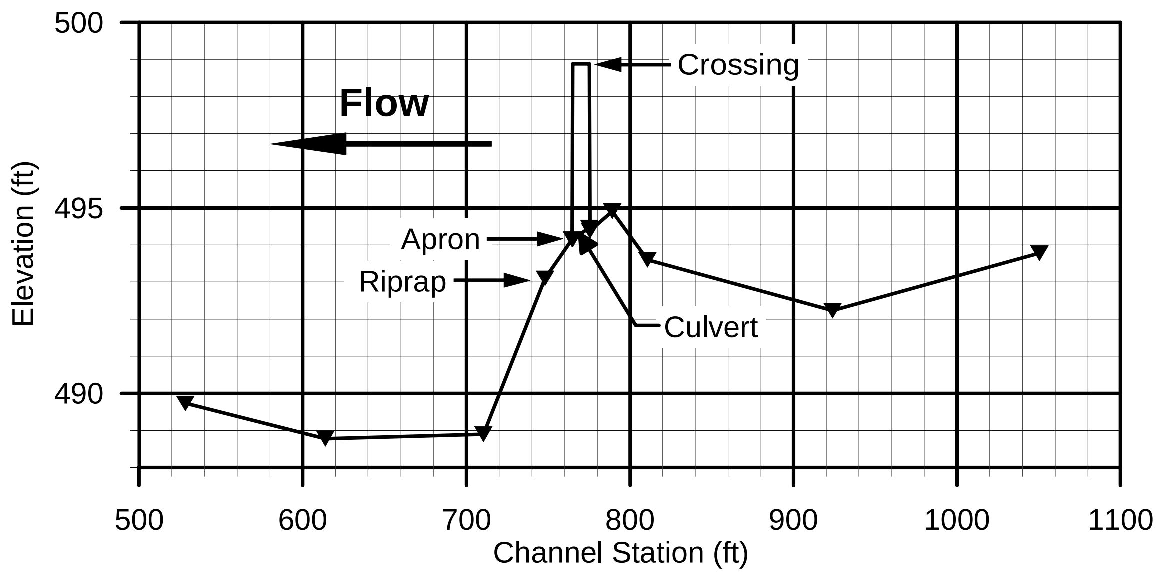


Figure 5-14. Depth curves for Caprini Low Flow Road Crossing

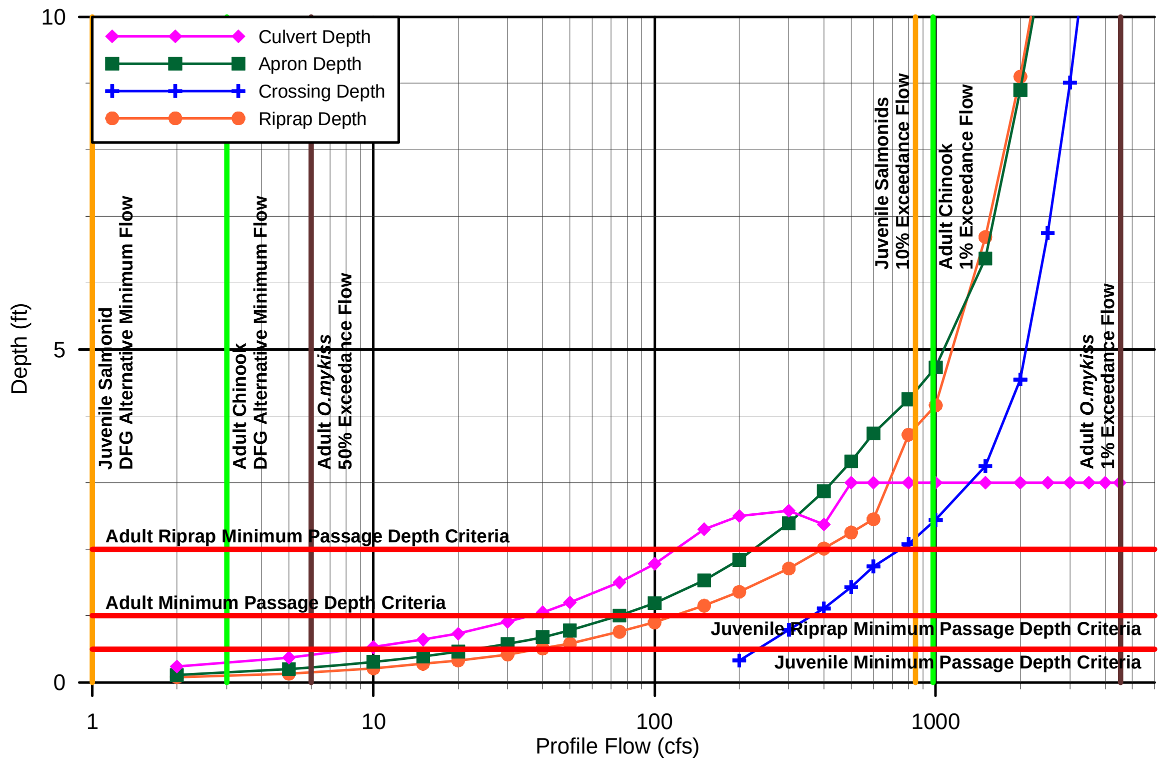


Figure 5-15. Velocity curves for Caprini Low Flow Road Crossing

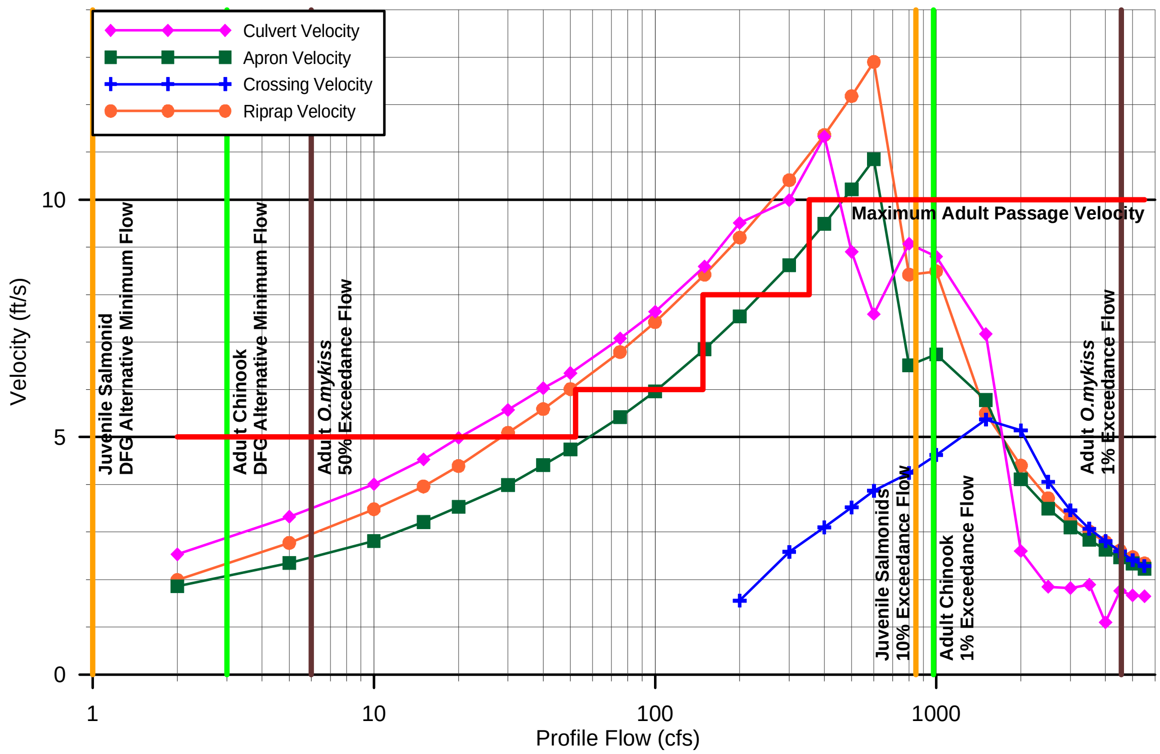


Figure 5-16. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Caprini LFC, Sep through Dec

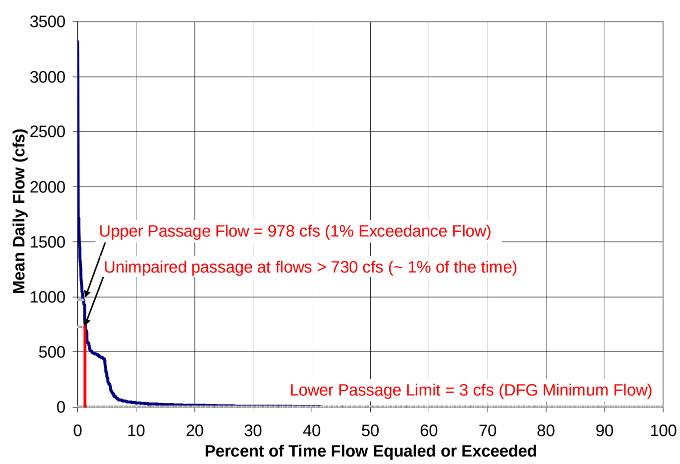


Figure 5-17. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Caprini LFC, Oct through Mar

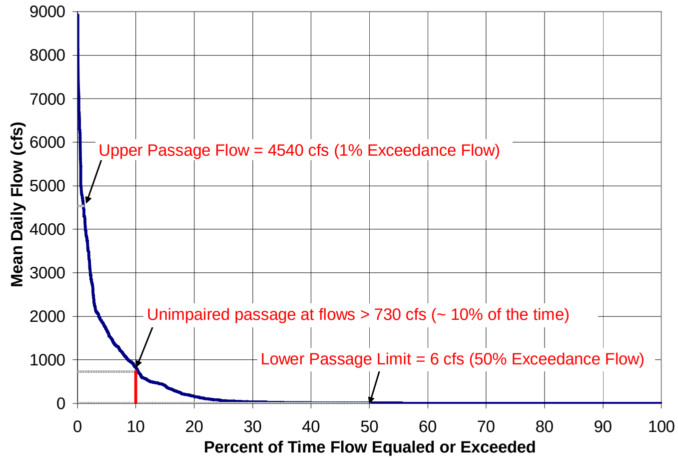


Figure 5-18. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Caprini LFC, Jan through June

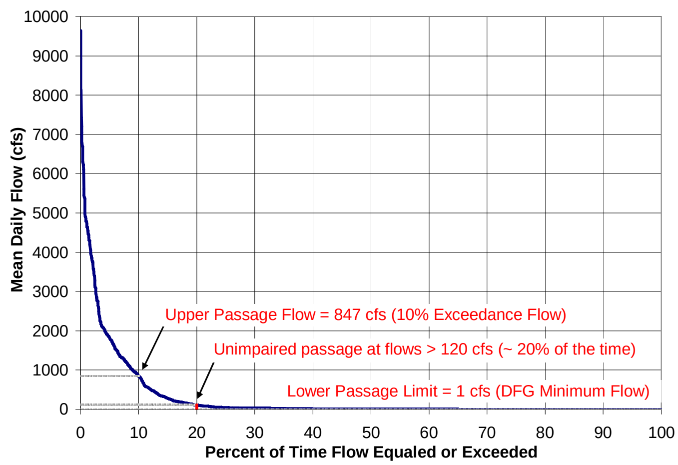


Figure 5-19. Longitudinal profile at Hogan Low Flow Road Crossing

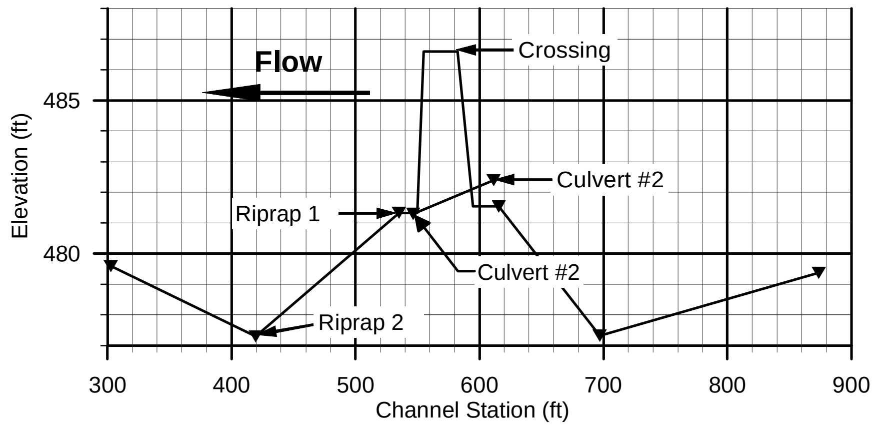


Figure 5-20. Depth curves for Hogan Low Flow Road Crossing

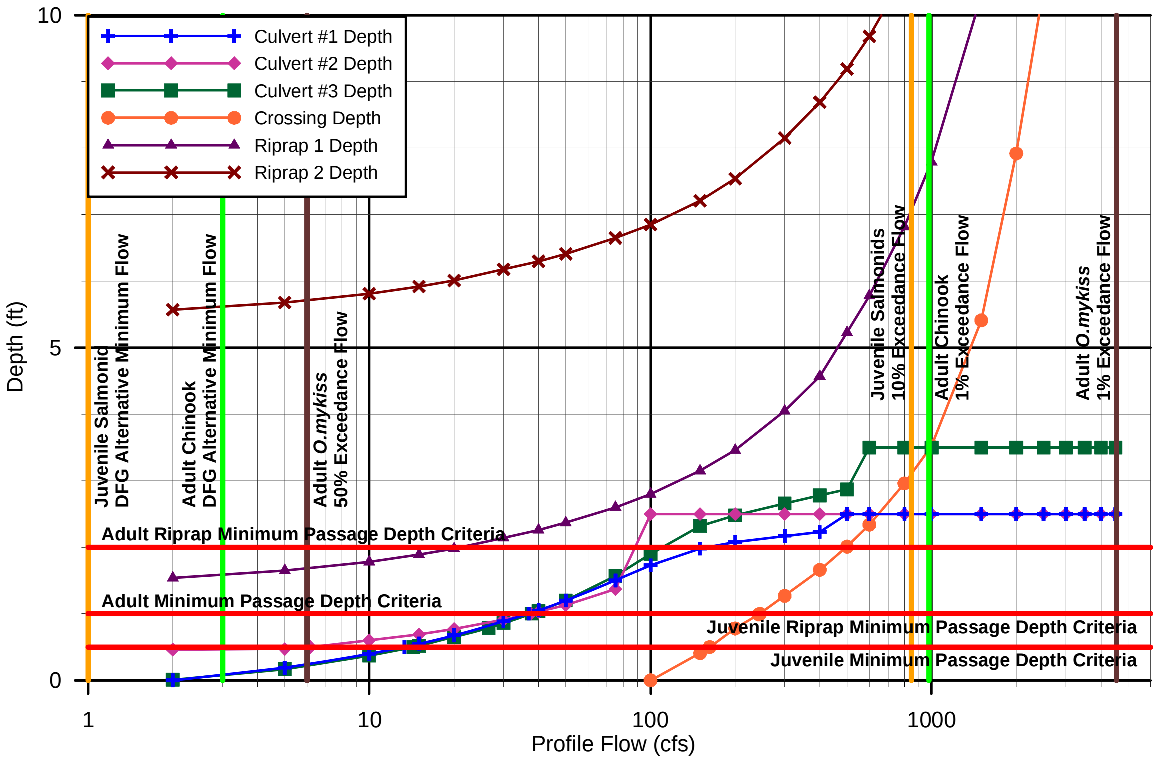


Figure 5-21. Velocity curves for Hogan Low Flow Road Crossing

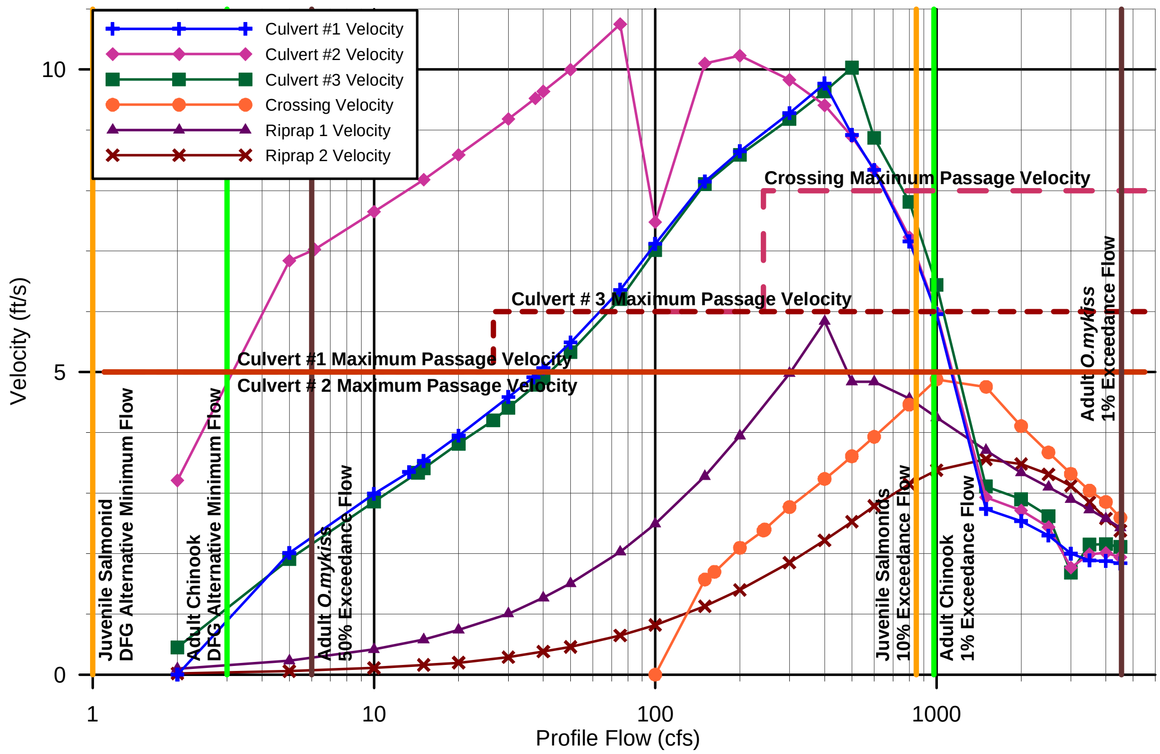


Figure 5-22. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Hogan LFC, Sep through Dec

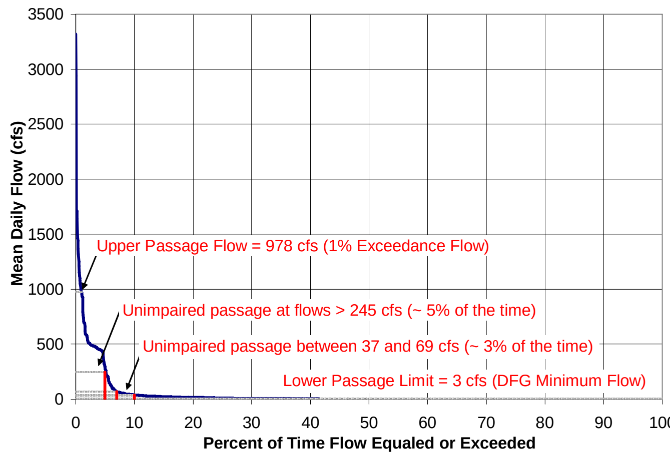


Figure 5-23. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Hogan LFC, Oct through Mar

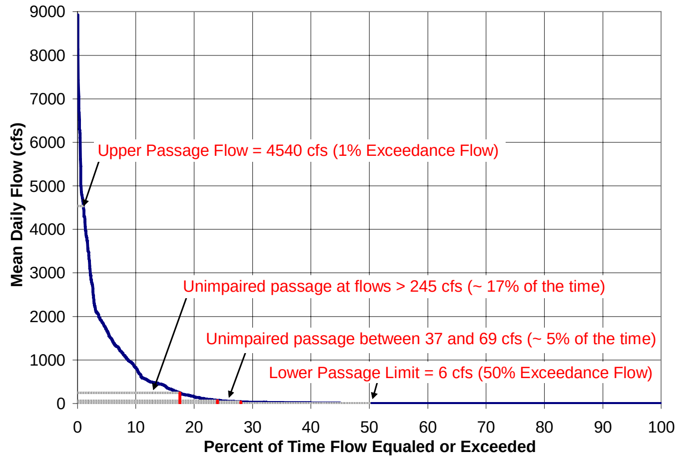


Figure 5-24. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Hogan LFC, Jan through June

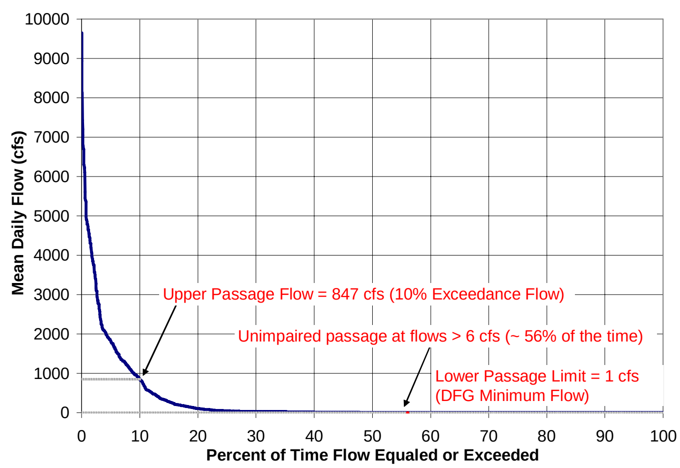


Figure 5-25. Longitudinal profile at Hosie Low Flow Road Crossing

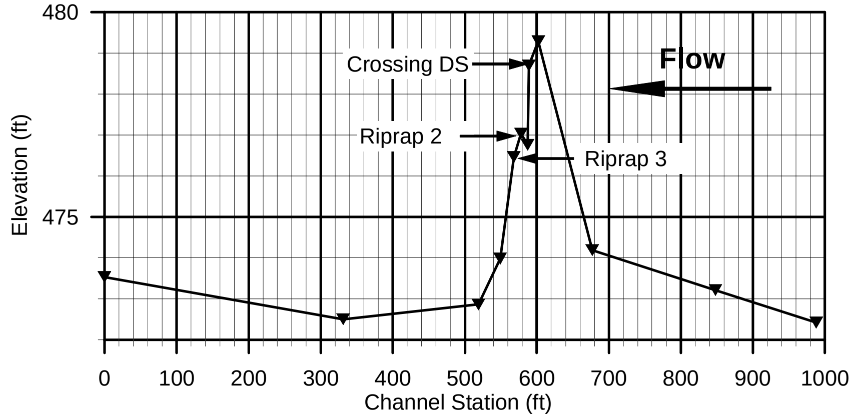


Figure 5-26. Depth curves for Hosie Low Flow Road Crossing

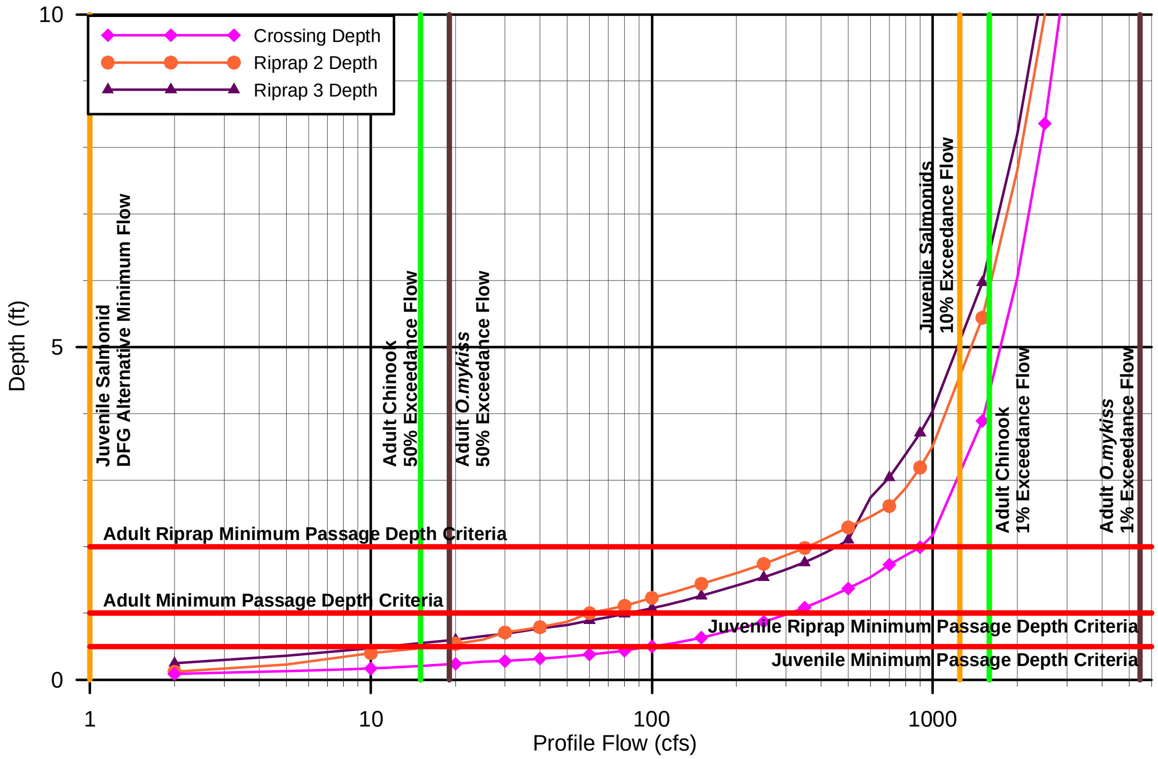


Figure 5-27. Velocity curves for Hosie Low Flow Road Crossing

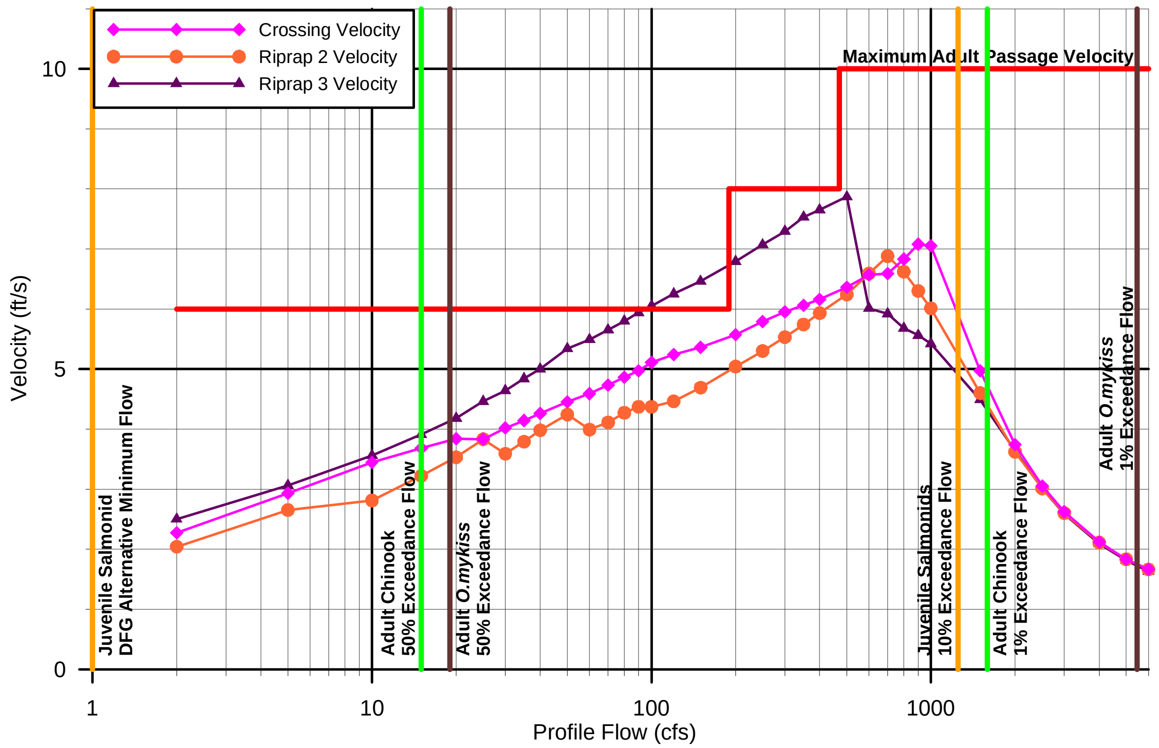


Figure 5-28. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Hosie LFC, Sep through Dec

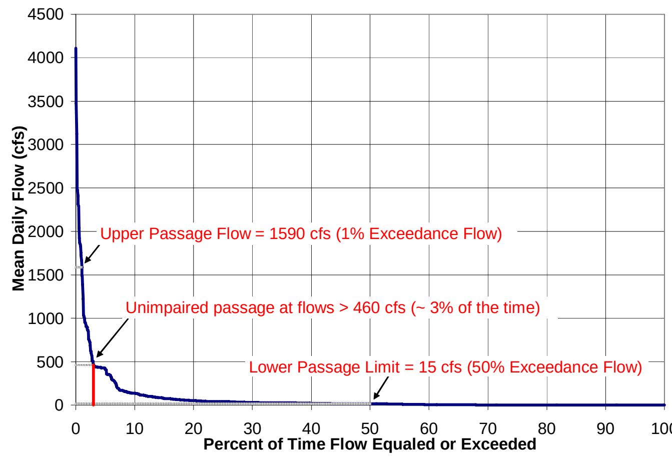


Figure 5-29. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Hosie LFC, Oct through Mar

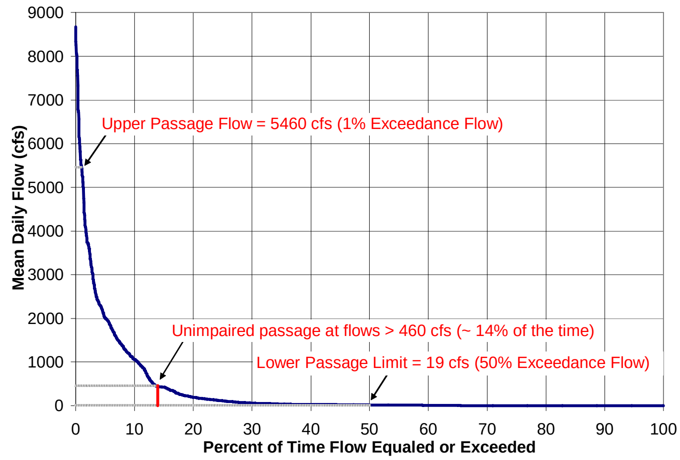


Figure 5-30. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Hosie LFC, Jan through June

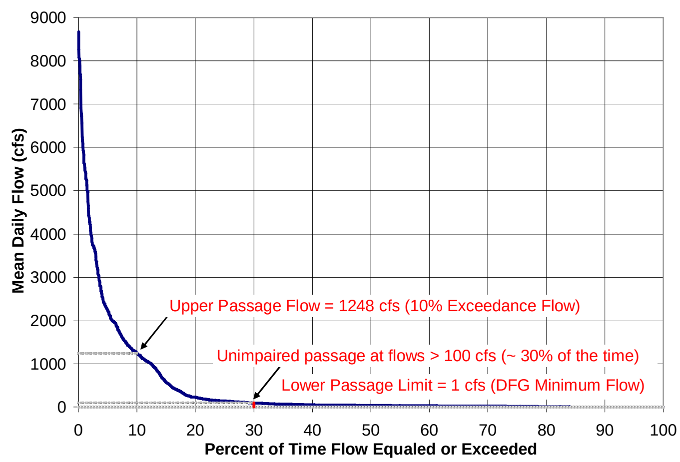


Figure 5-31. Longitudinal profile for Watkins Low Flow Road Crossing

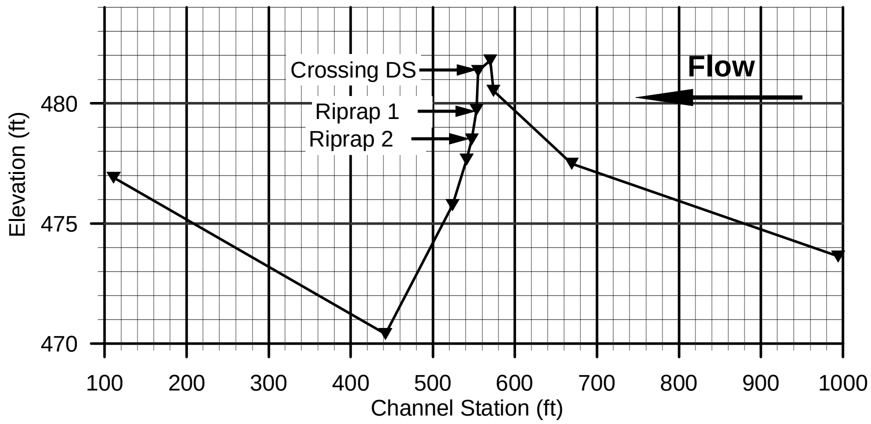


Figure 5-32. Depth curves for Watkins Low Flow Road Crossing

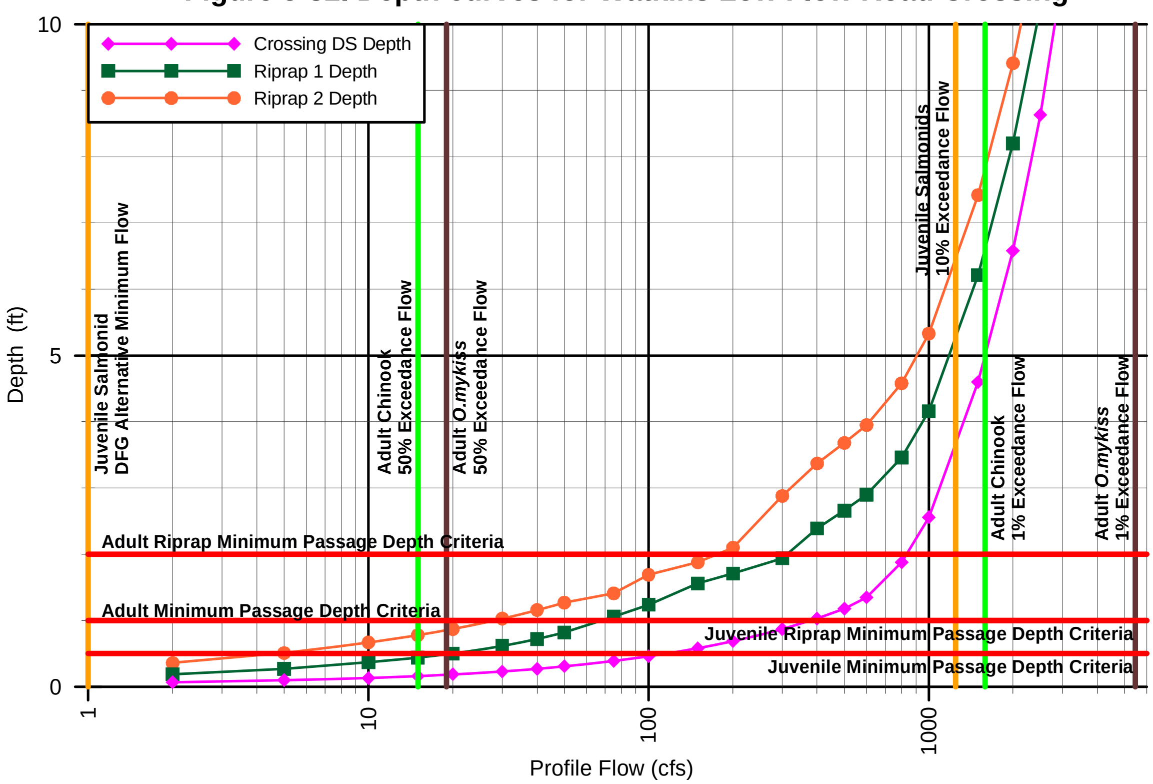


Figure 5-33. Velocity curves for Watkins Low Flow Road Crossing

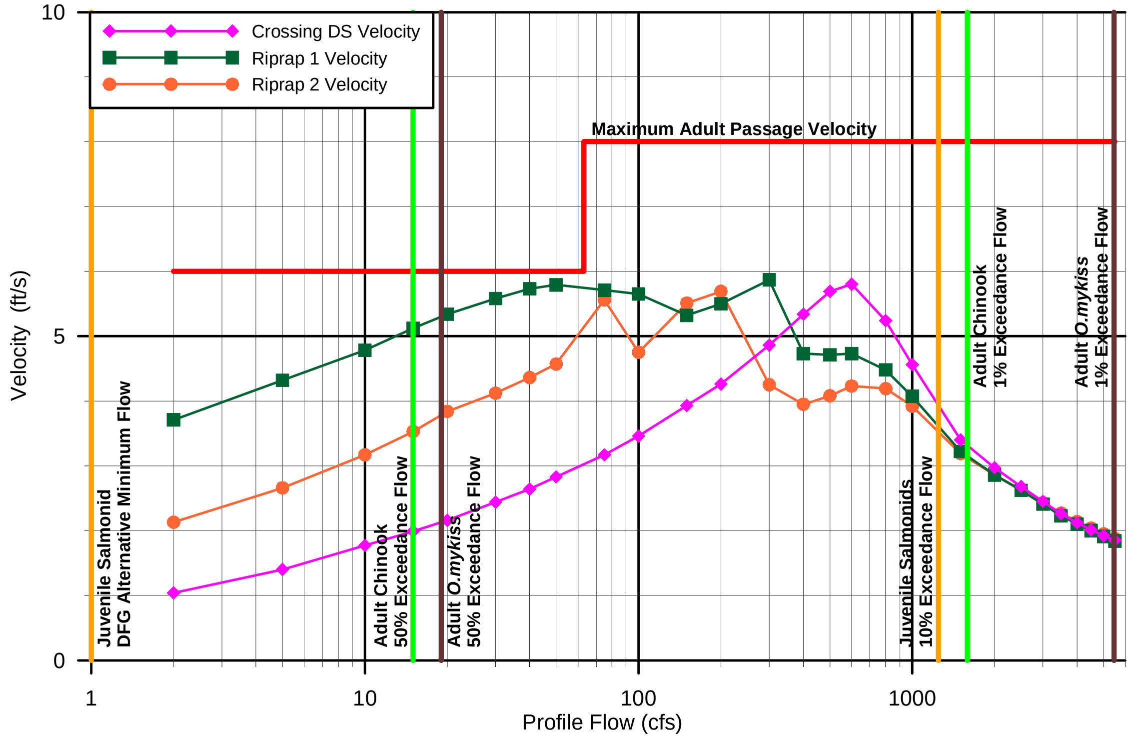


Figure 5-34. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Watkins LFC, Sep through Dec

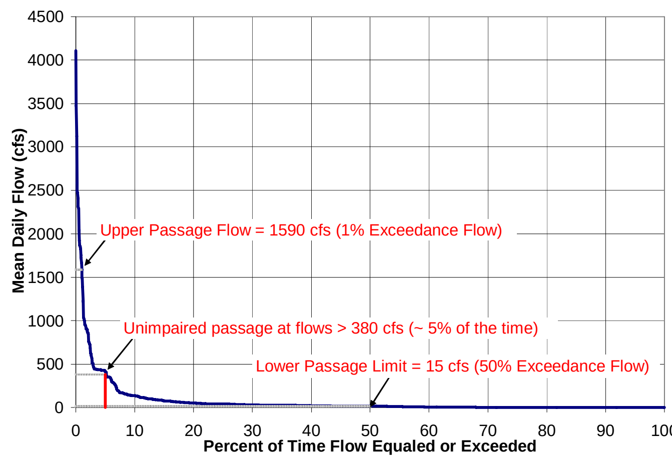


Figure 5-35. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Watkins LFC, Oct through Mar

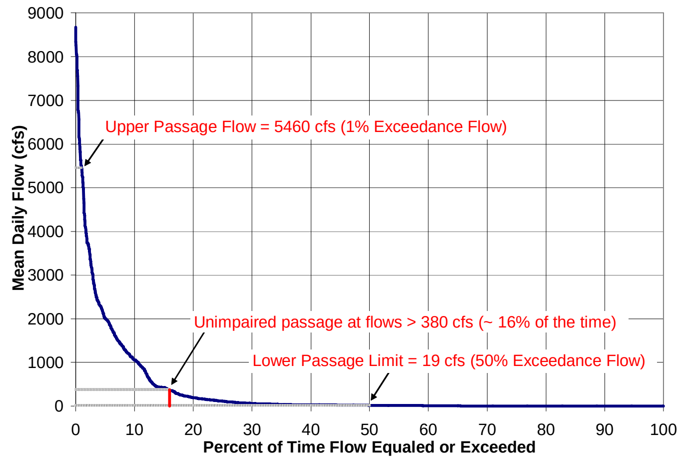


Figure 5-36. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Watkins LFC, Jan through June

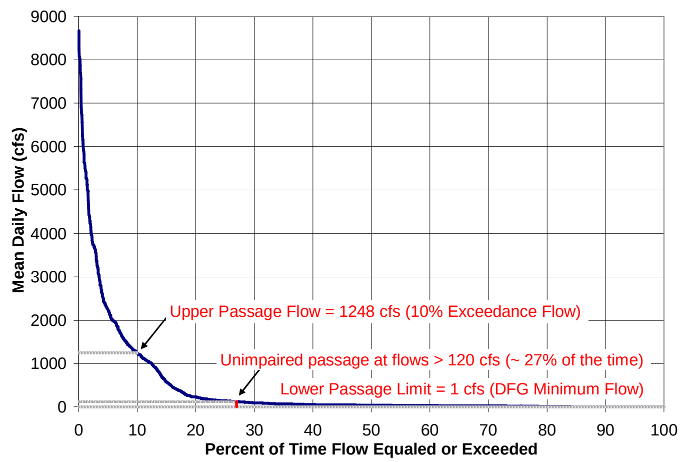


Figure 5-37. Longitudinal profile for Murphy Flashboard Dam

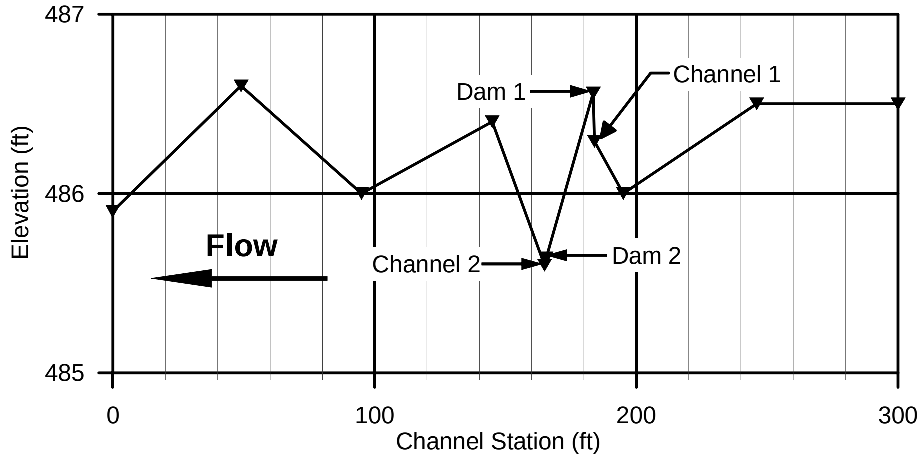


Figure 5-38. Depth curves for Murphy Flashboard Dam

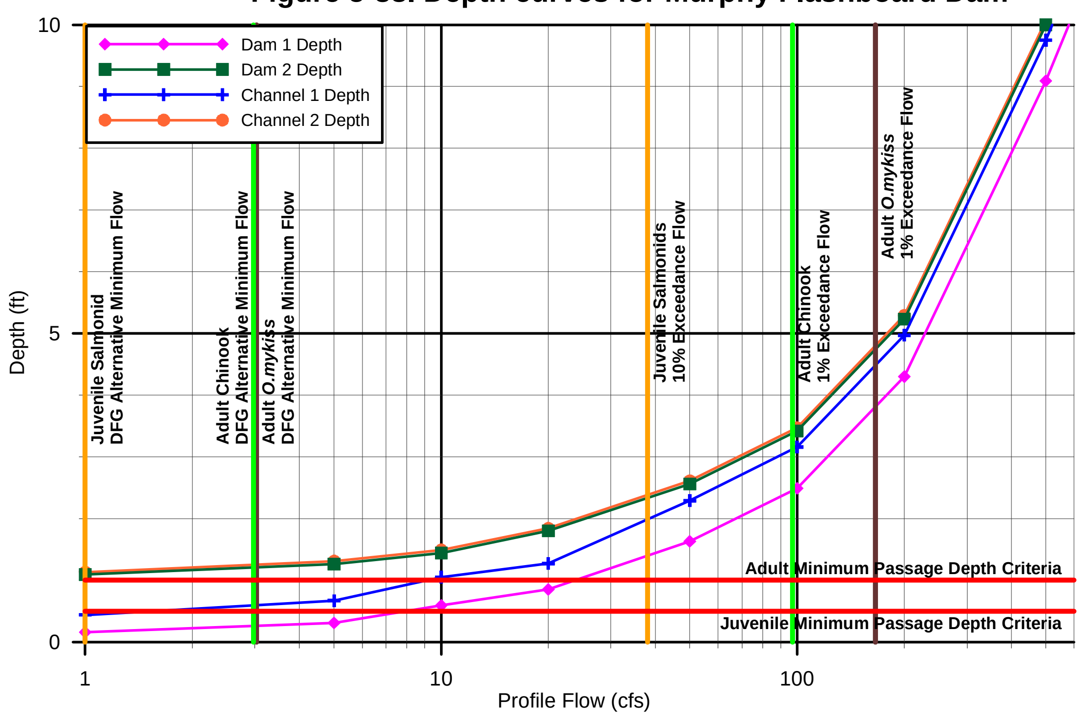


Figure 5-39. Velocity curves for Murphy Flashboard Dam

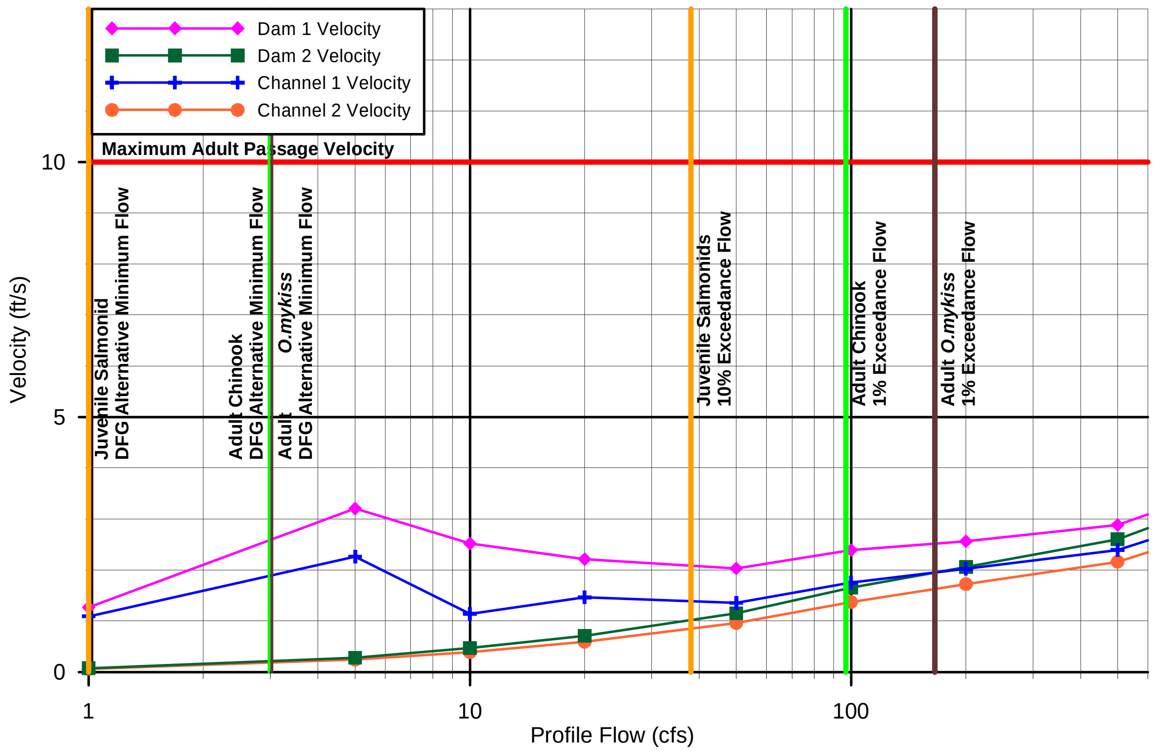


Figure 5-40. Calaveras River from the Headworks to SDC flow duration curve showing adult Chinook passage performance at Murphy FBD, Sep through Dec

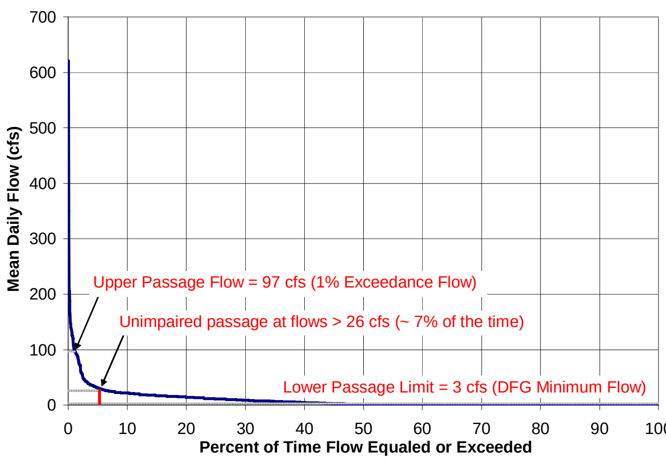


Figure 5-41. Calaveras River from the Headworks to SDC flow duration curve showing adult *O. mykiss* passage performance at Murphy FBD, Oct through Mar

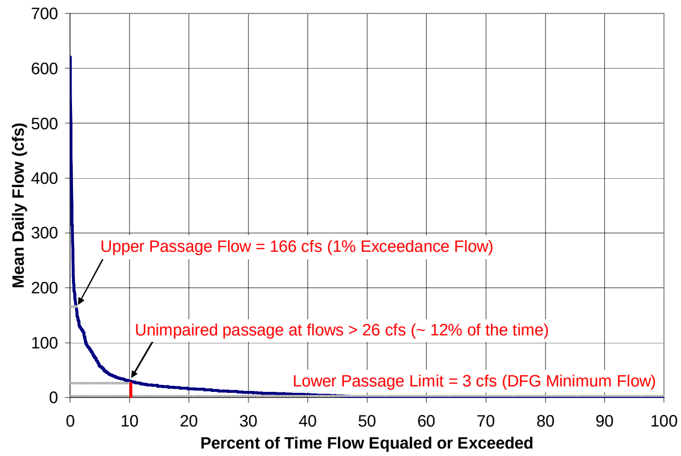


Figure 5-42. Calaveras River from the Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Murphy FBD, Jan through June

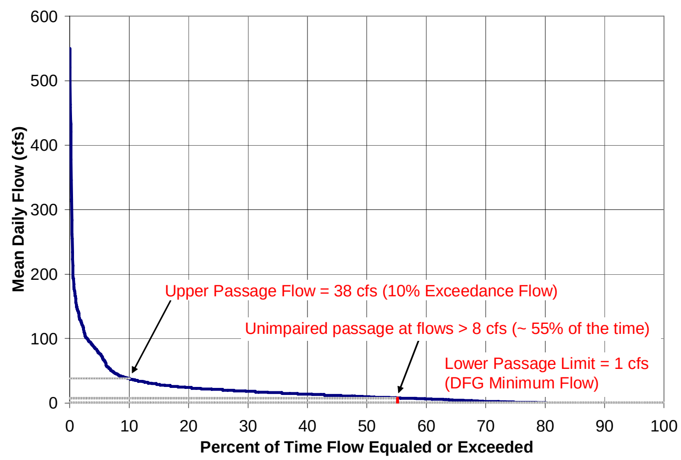


Figure 5-43. Longitudinal profile at Clements Road Flashboard Dam

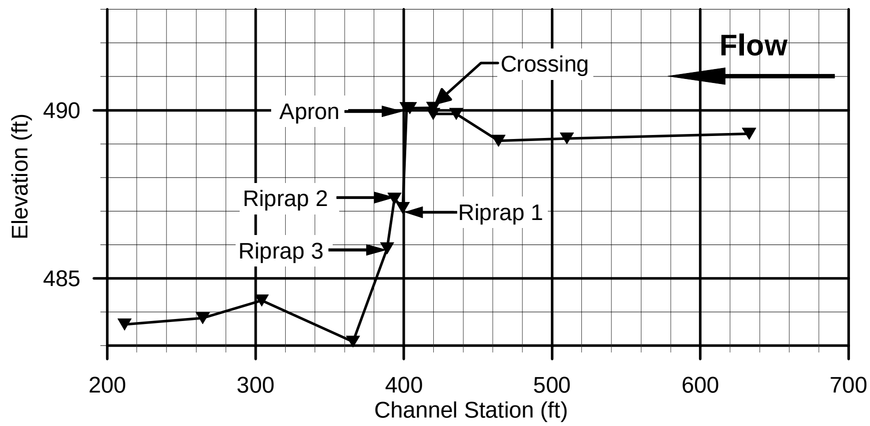


Figure 5-44. Depth curves for Clements Road Flashboard Dam

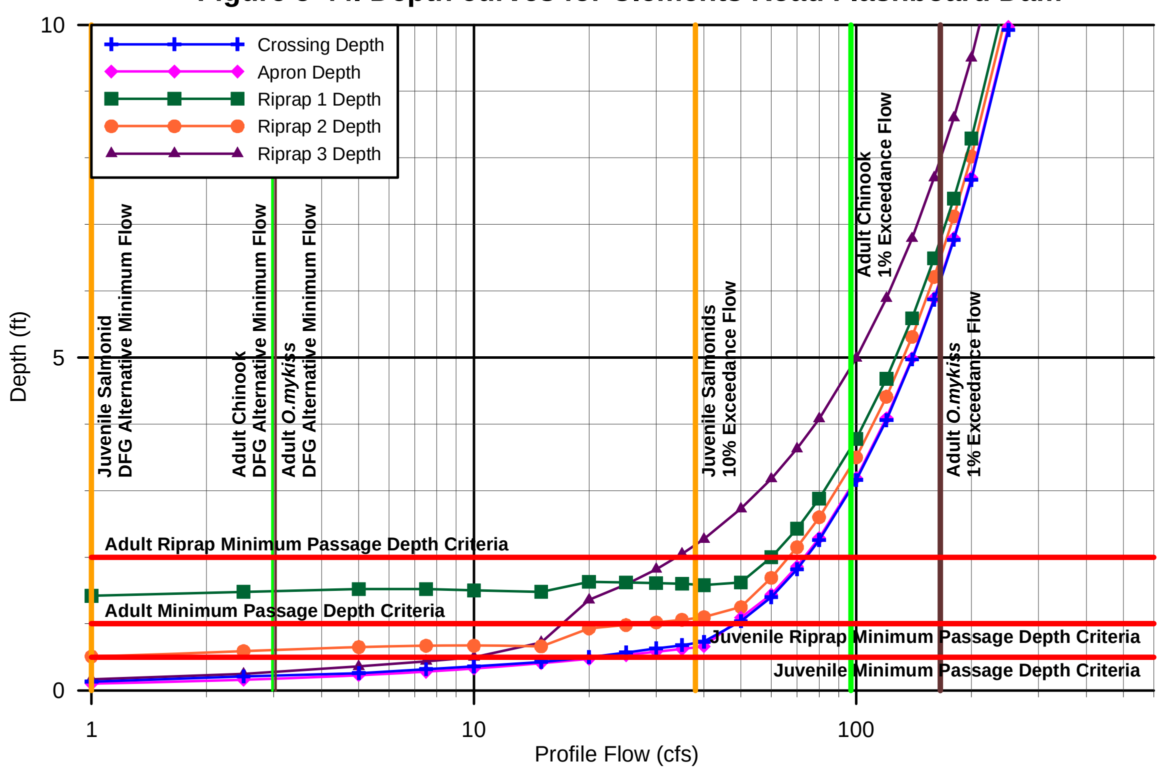


Figure 5-45. Velocity curves for Clements Road Flashboard Dam

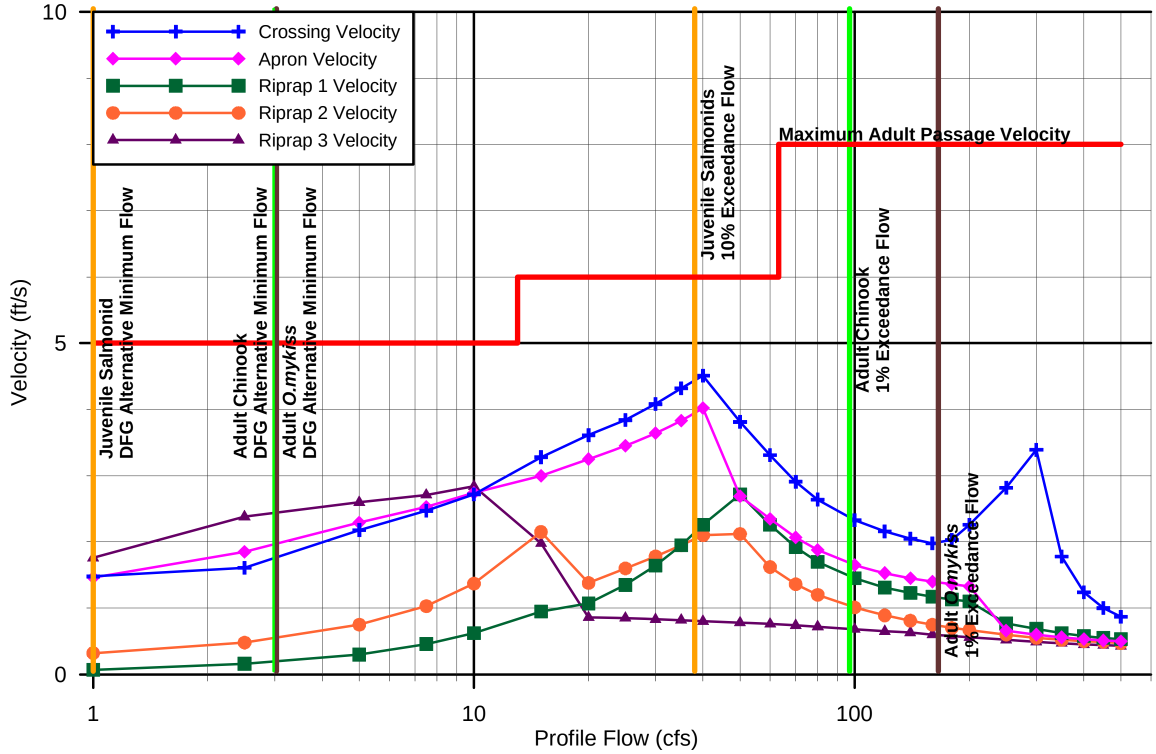


Figure 5-46. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at Clements FBD, Sep through Dec

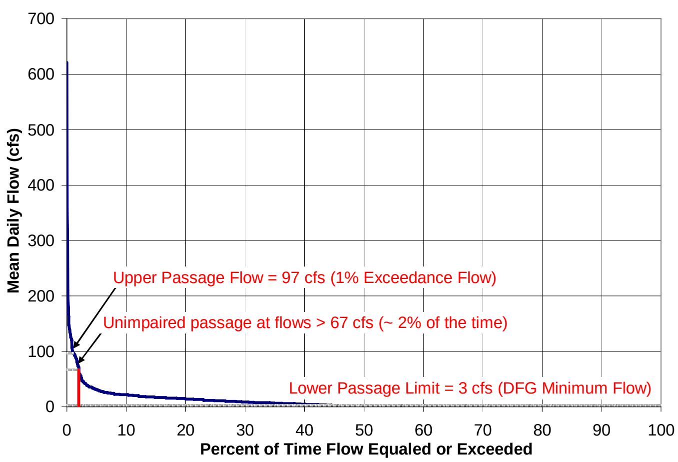


Figure 5-47. Calaveras River Headworks to SDC flow duration curve showing adult *O. mykiss* passage performance at Clements FBD, Oct through Mar

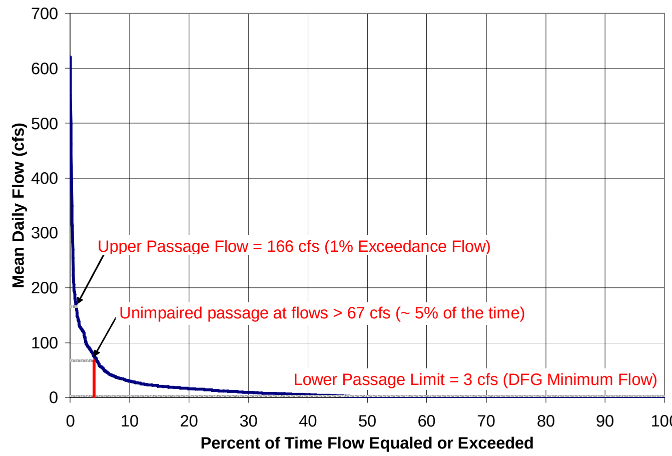


Figure 5-48. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Clements FBD, Jan through June

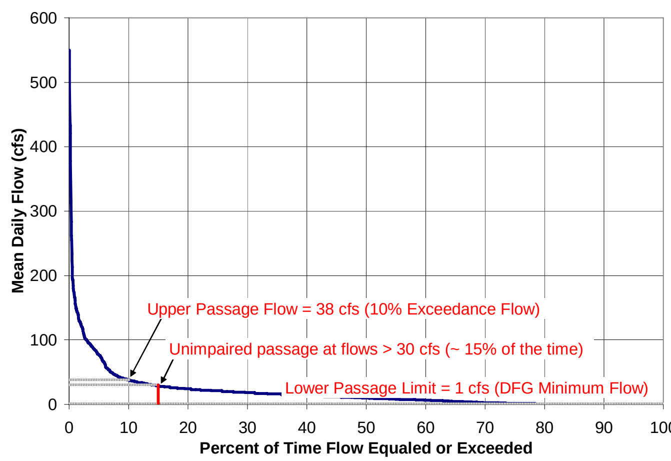


Figure 5-49. Longitudinal profile at Lavaggi Flashboard Dam

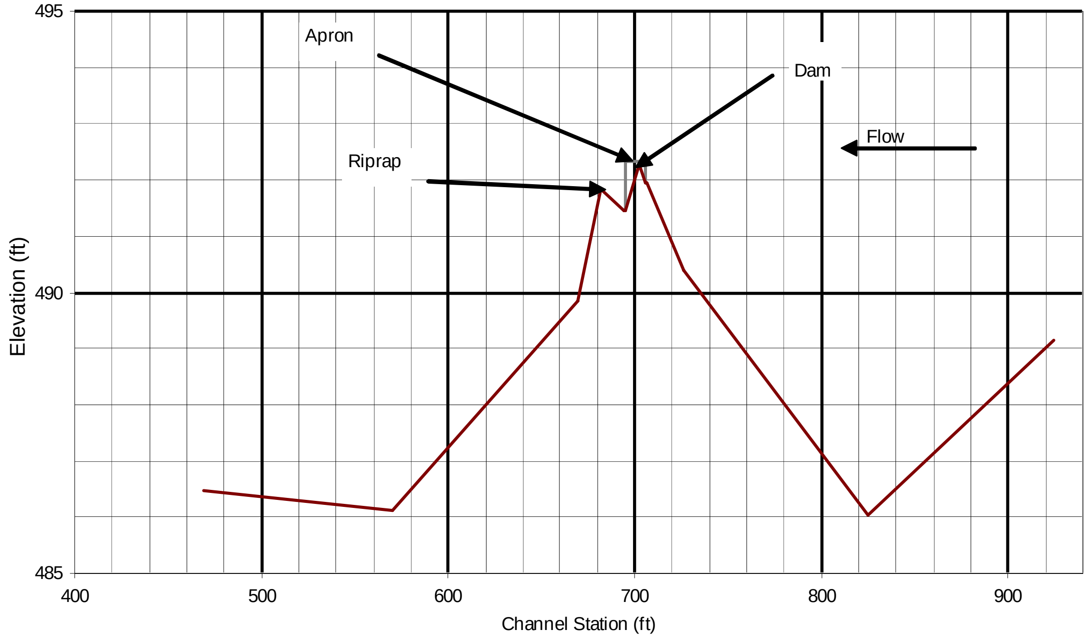


Figure 5-50. Depth curves for Lavaggi Flashboard Dam

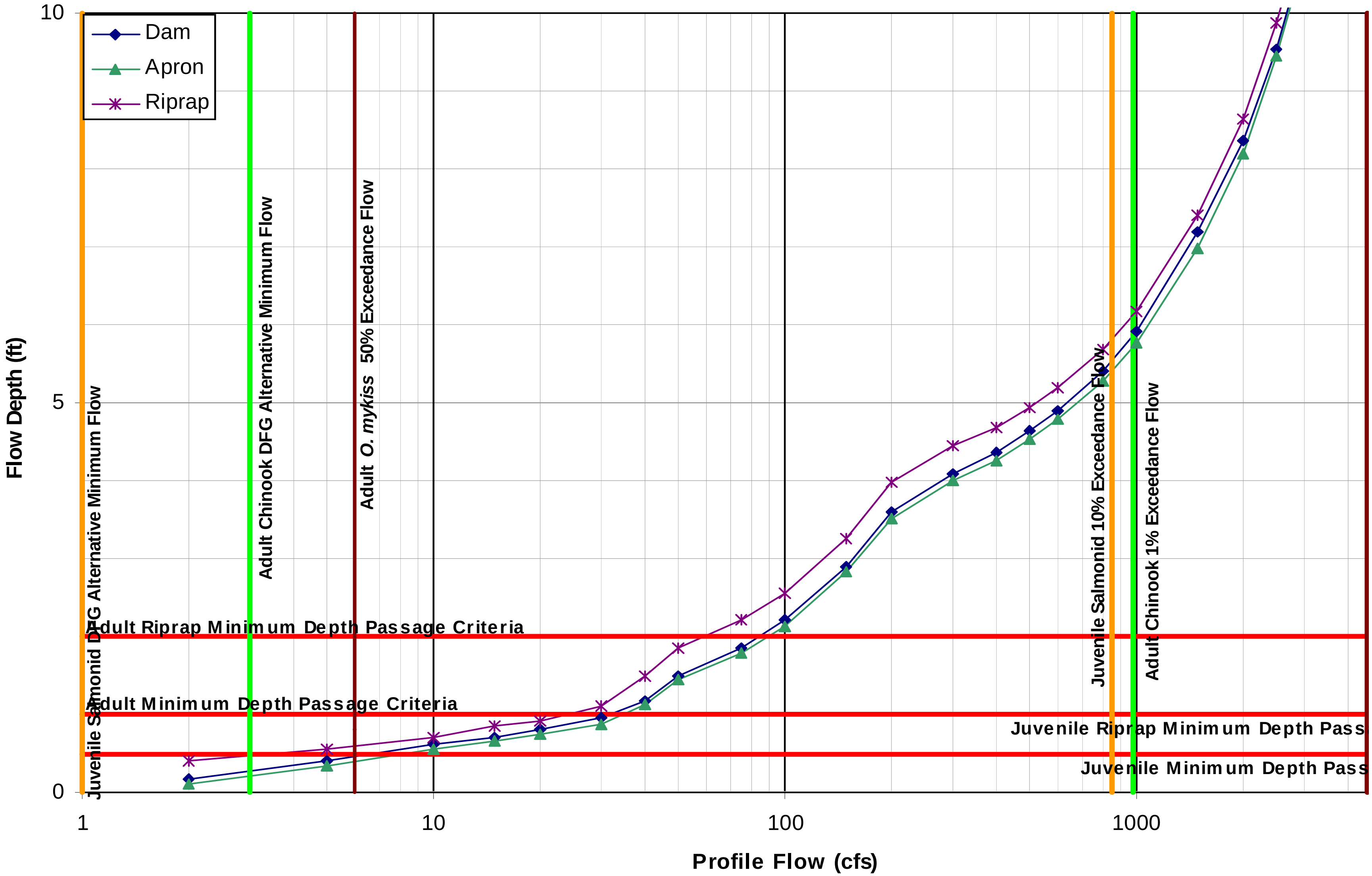


Figure 5-51. Velocity curves for Lavaggi Flashboard Dam

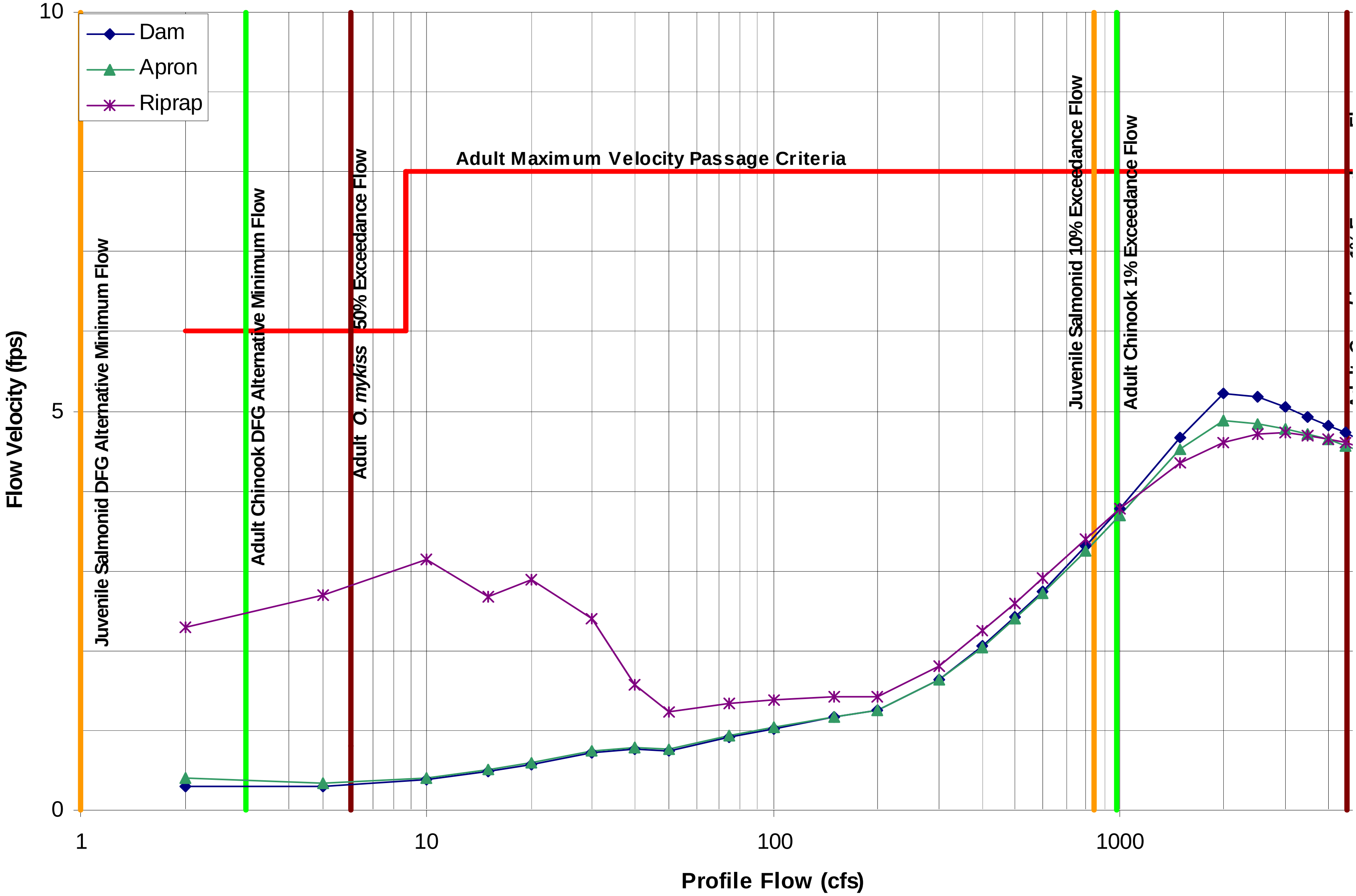


Figure 5-52. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Lavaggi, Sep through Dec

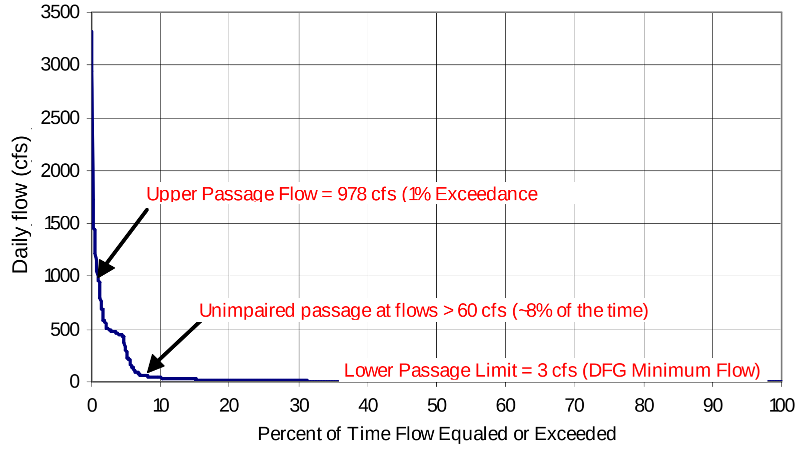


Figure 5-53. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Lavaggi, Oct through Mar

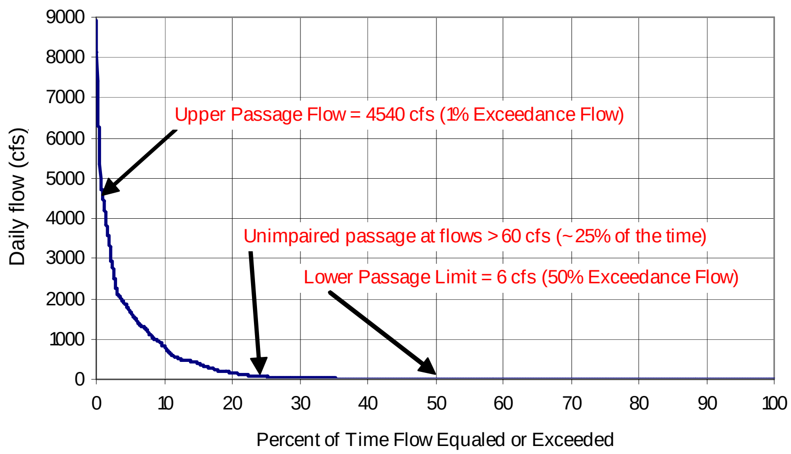


Figure 5-54. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Lavaggi, Jan through June

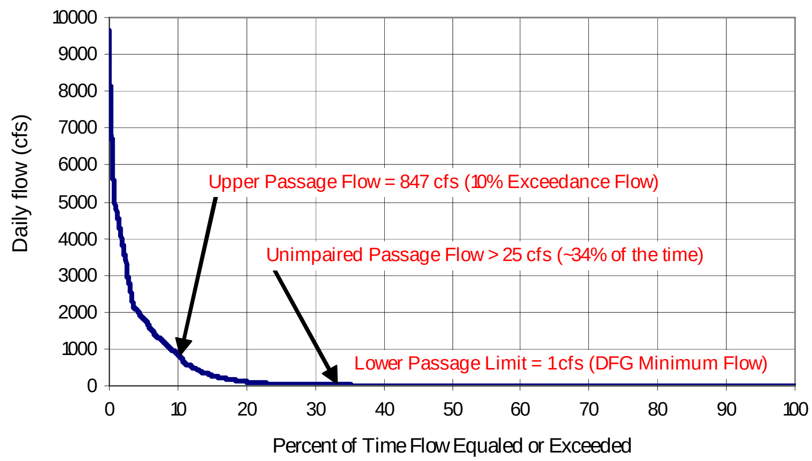


Figure 5-55. Longitudinal profile for Fujinaka Low-flow Road Crossing

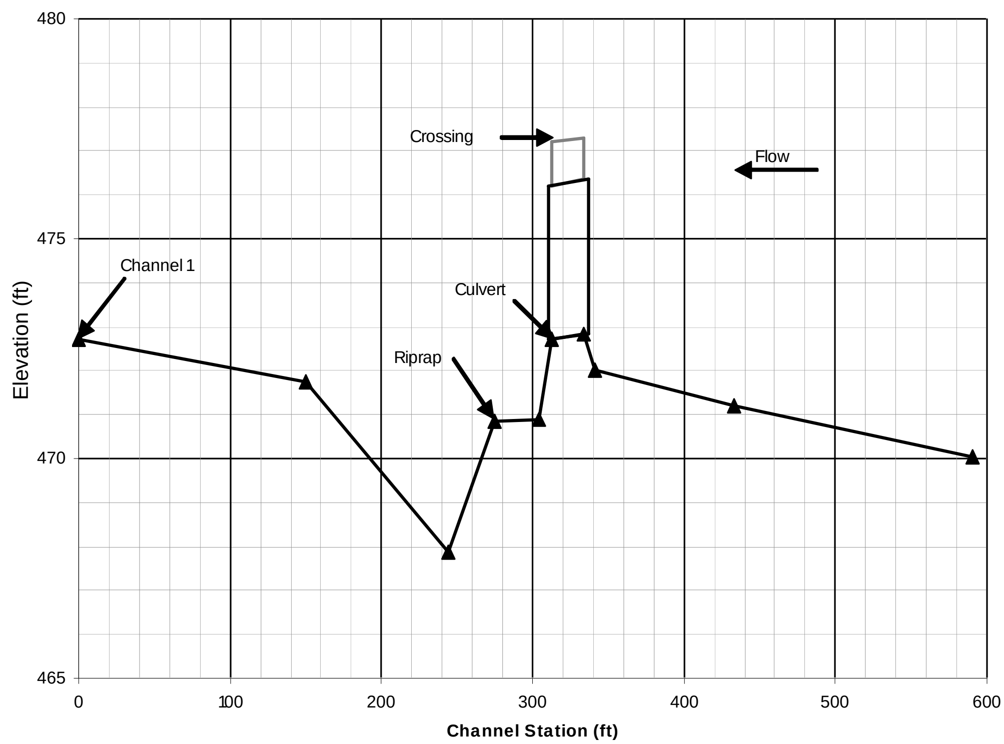


Figure 5-56. Depth curves for Fujinaka Low-flow Road Crossing

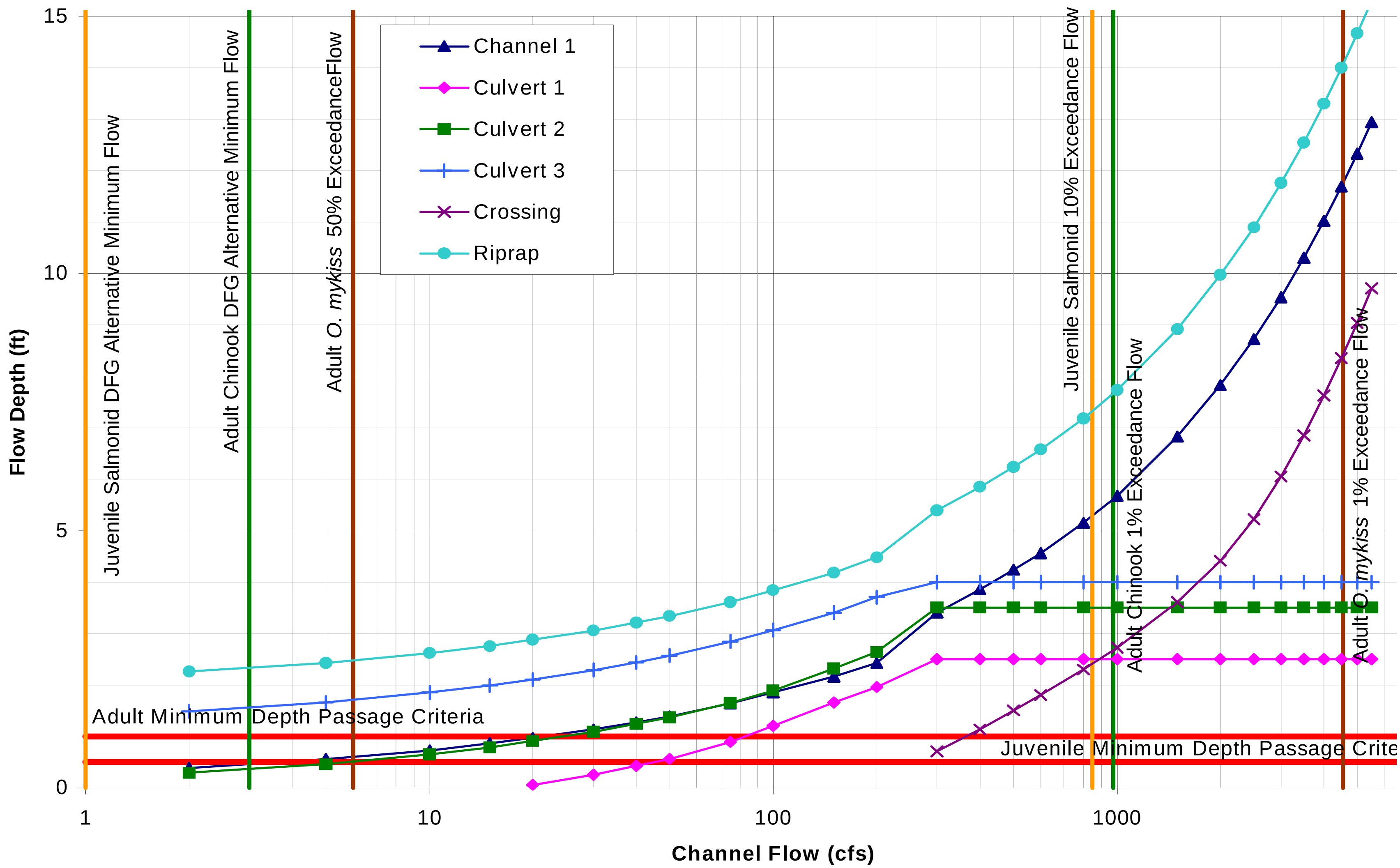


Figure 5-57. Velocity curves for Fujinaka Low-flow Road Crossing

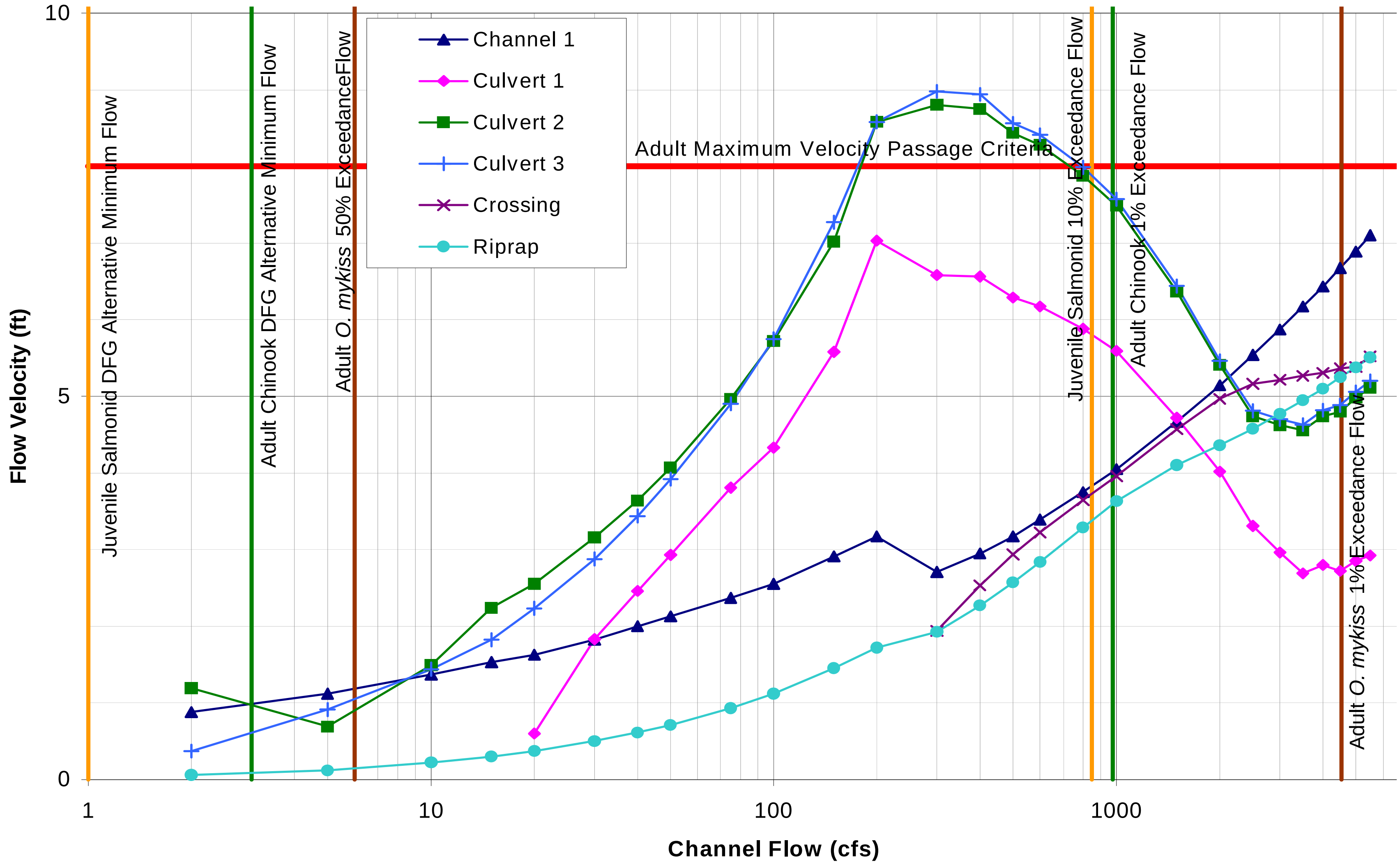


Figure 5-58. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Fujinaka LFC, Sep through Dec

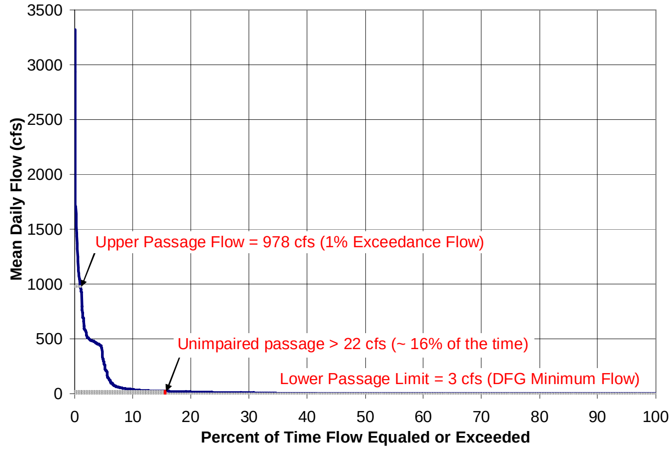


Figure 5-59. Mormon Slough downstream of MSRR Bridge flow duration curve showing adult *O. mykiss* passage performance at Fujinaka LFC, Oct through Mar

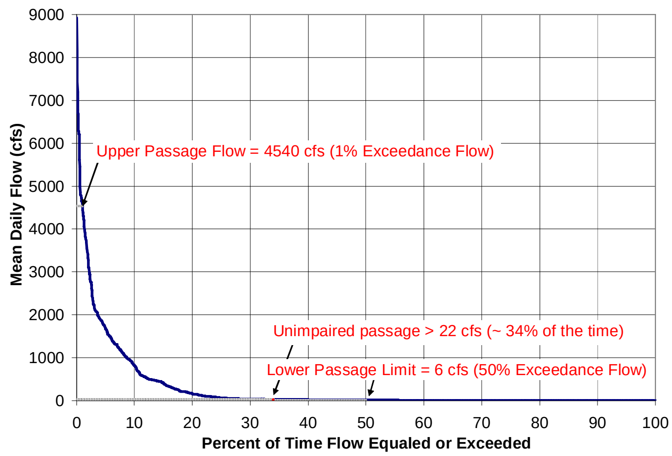


Figure 5-60. Mormon Slough downstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Fujinaka LFC, Jan through June

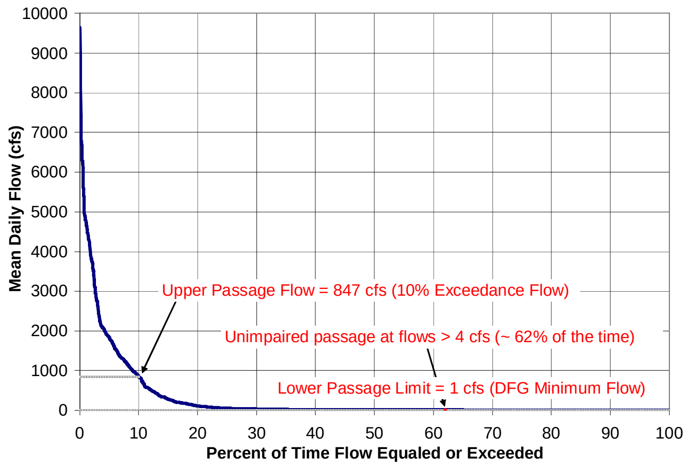


Figure 5-61. Longitudinal profile at Mormon Slough Railroad Bridge

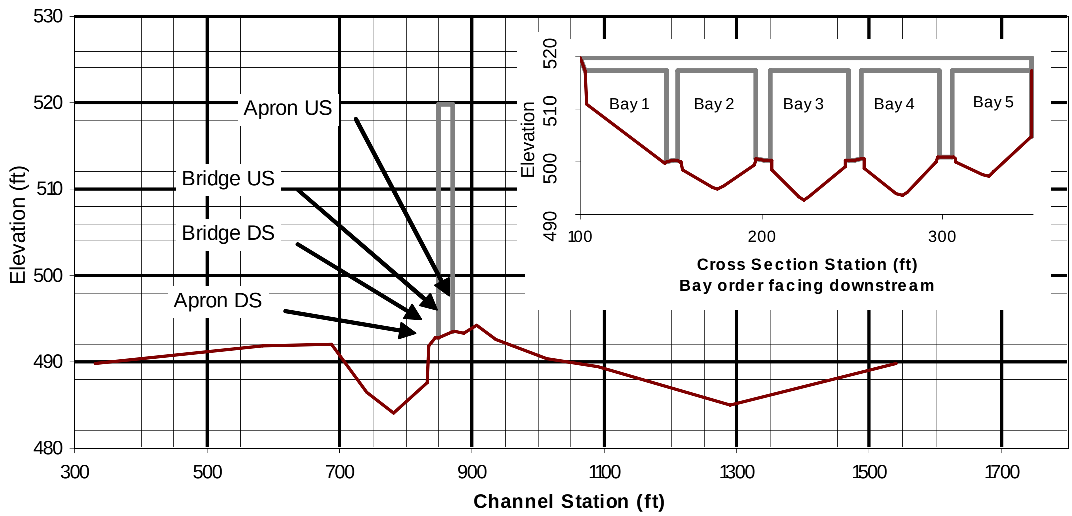


Figure 5-62. Depth curves for Mormon Slough Railroad Bridge

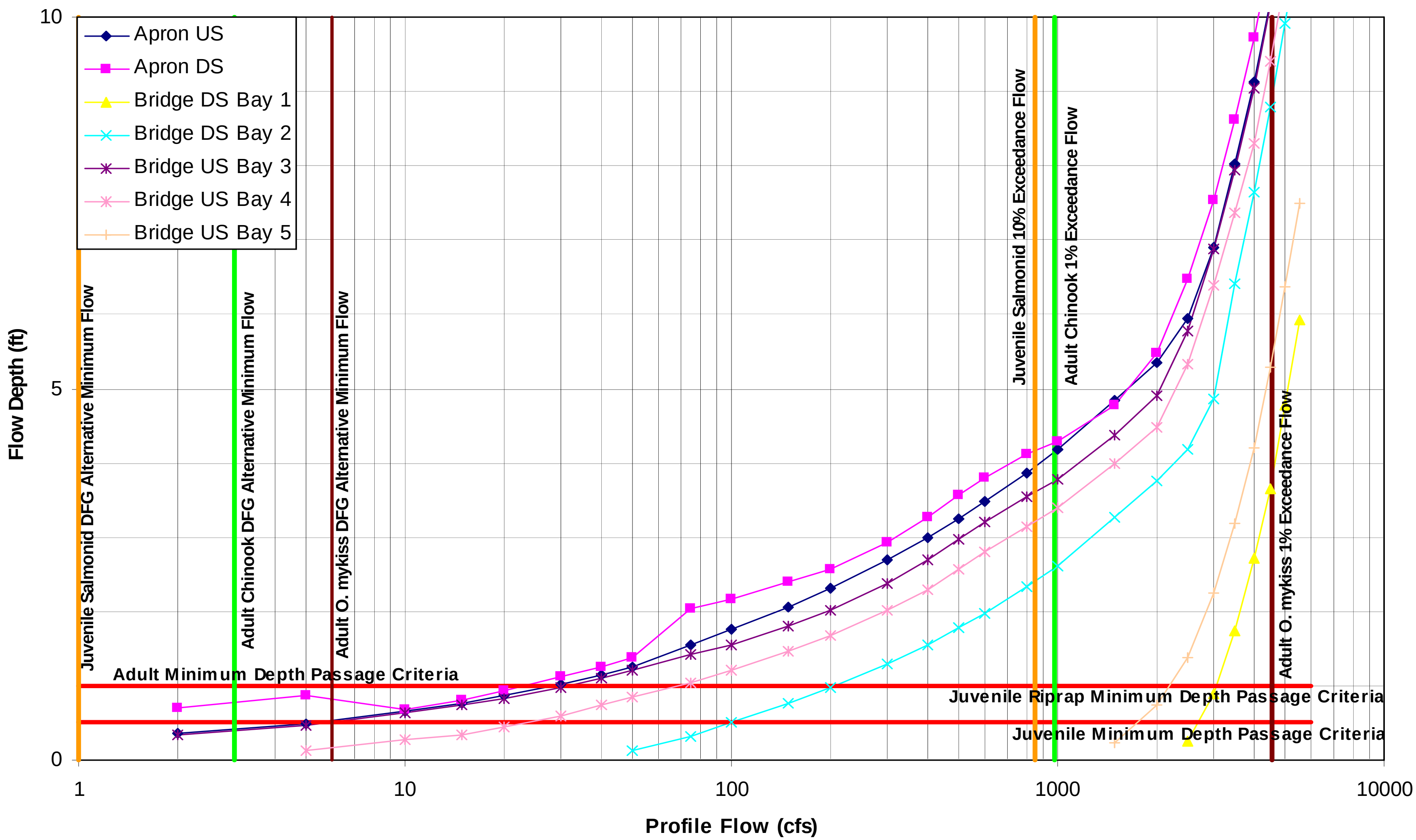


Figure 5-63. Velocity curves for Mormon Slough Railroad Bridge

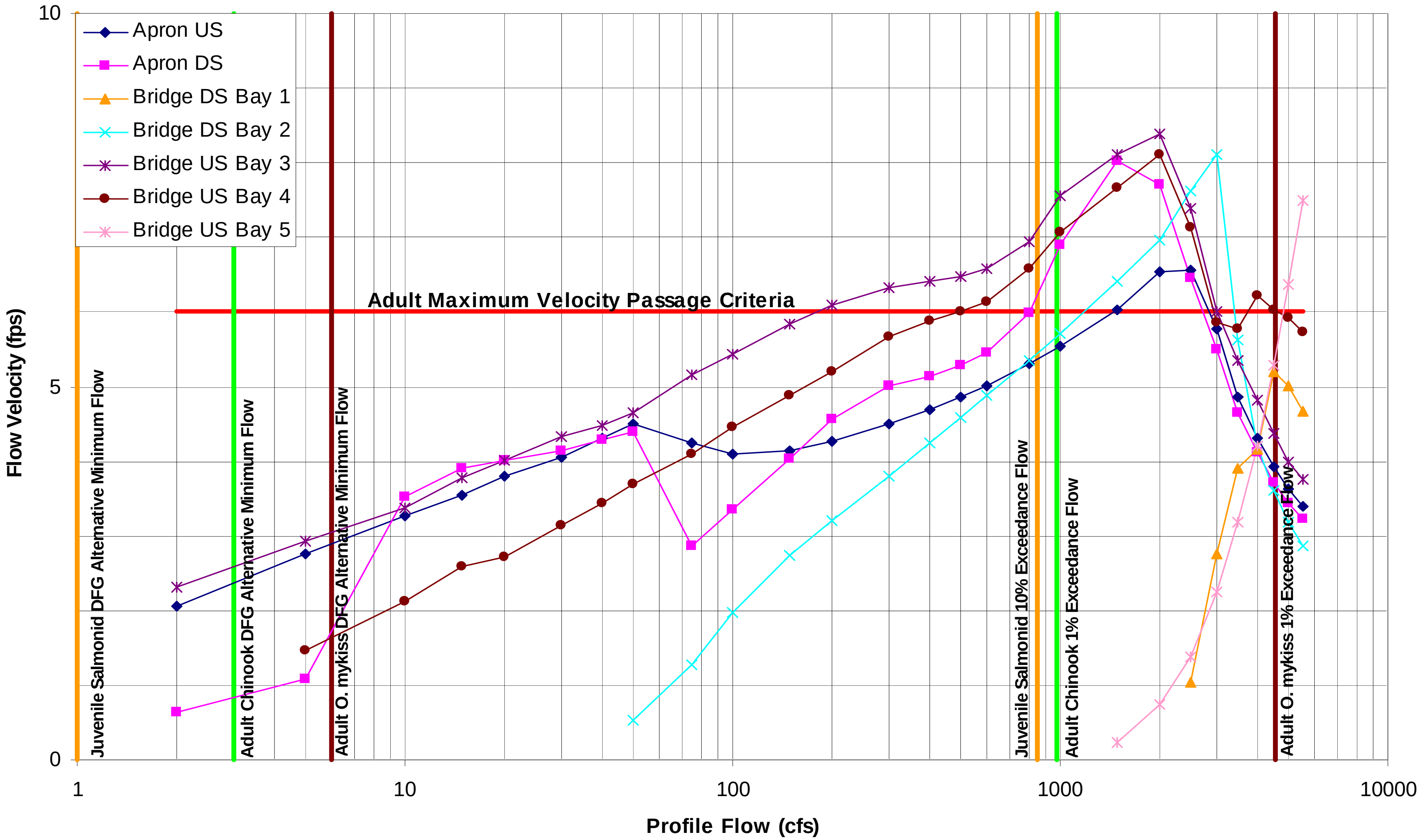


Figure 5-64. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at MSRR Bridge, Sep through Dec

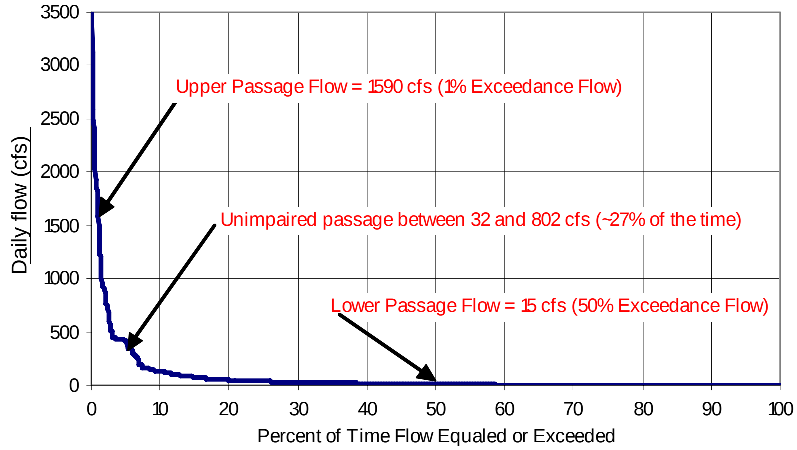


Figure 5-65. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult O. mykiss passage performance at MSRR Bridge, Oct through Mar

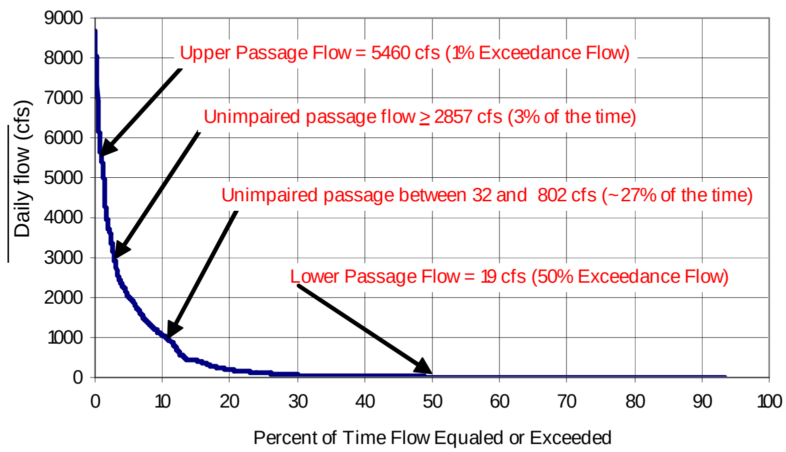


Figure 5-66. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at MSRR Bridge, Jan through June

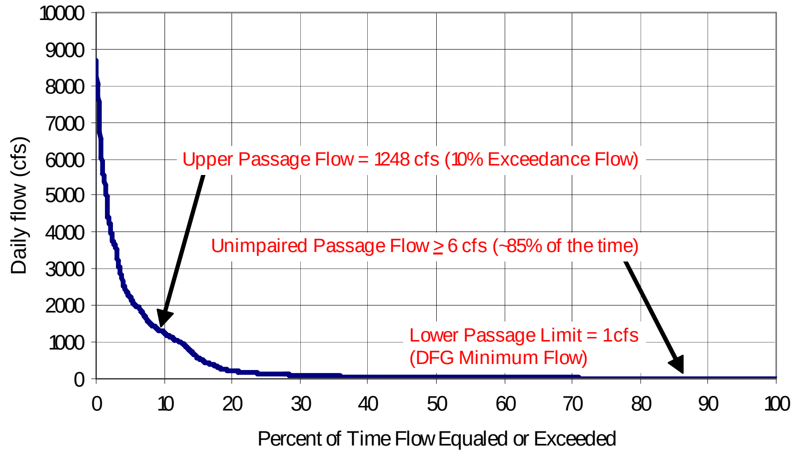


Figure 5-67. Longitudinal profile for Piazza Flashboard Dam

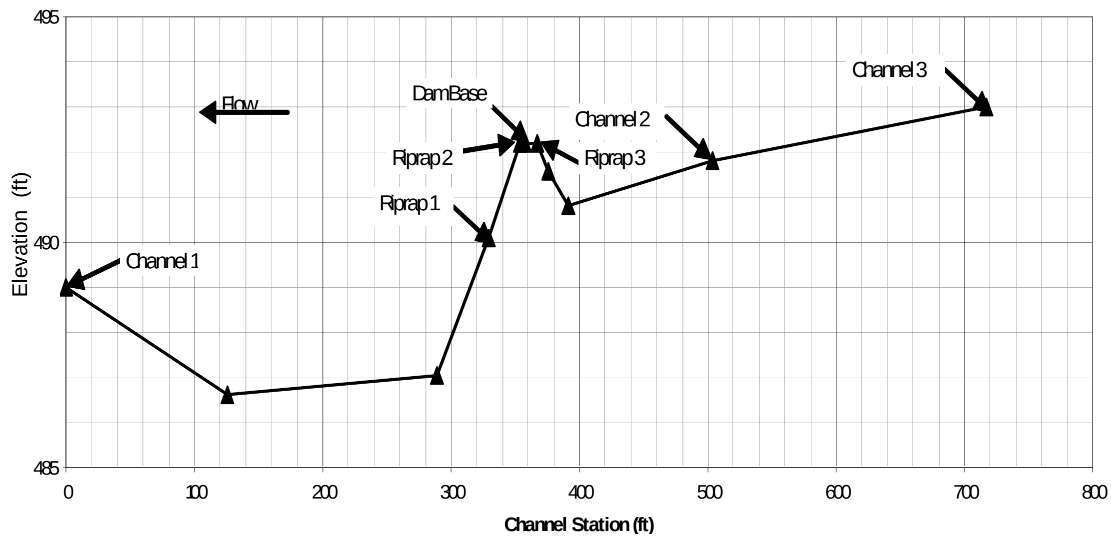


Figure 5-68. Depth curves for Piazza Flashboard Dam

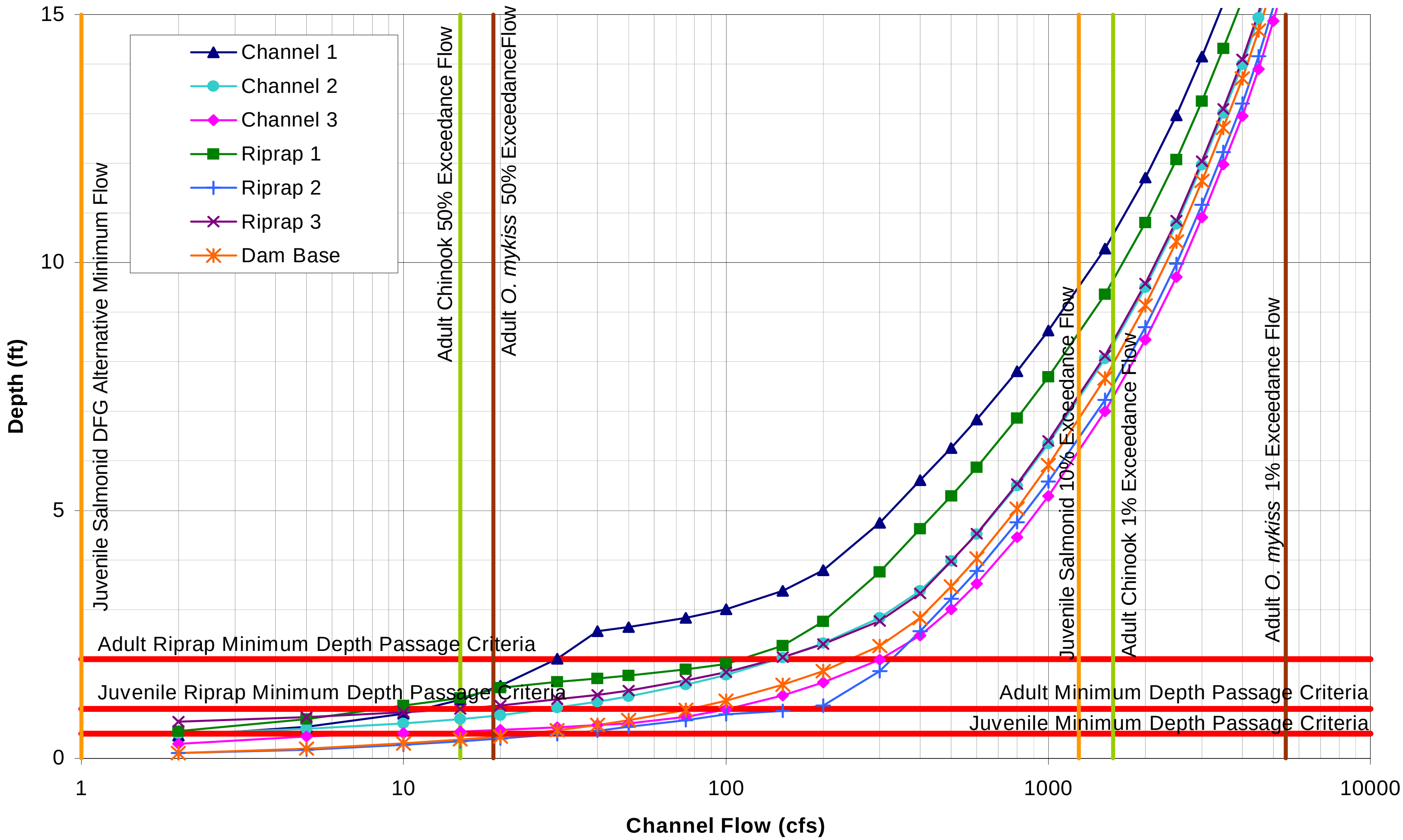


Figure 5-69. Velocity curves for Piazza Flashboard Dam

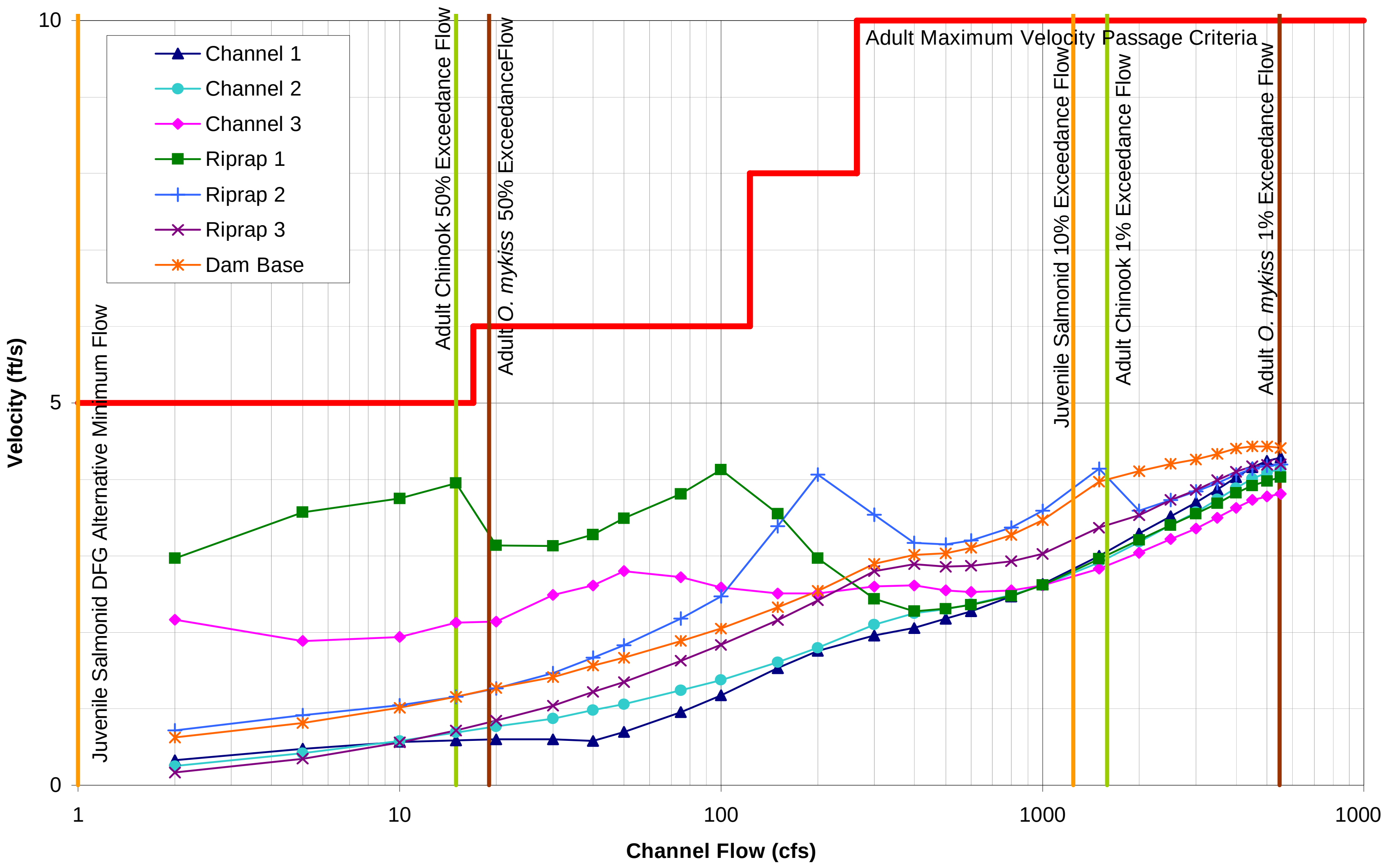


Figure 5-70. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult Chinook passage performance at Piazza, Sep through Dec

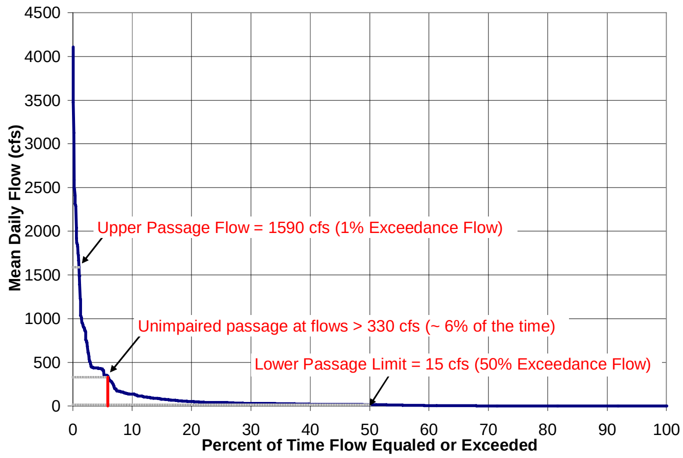


Figure 5-71. Mormon Slough upstream of MSRR Bridge flow duration curve showing adult O. mykiss passage performance at Piazza, Oct through Apr

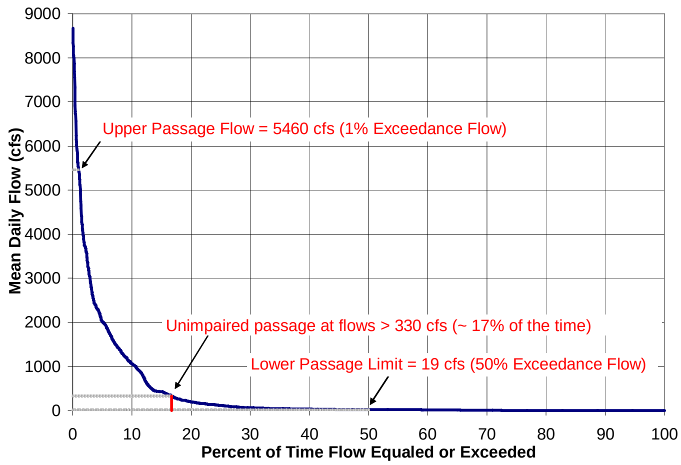


Figure 5-72. Mormon Slough upstream of MSRR Bridge flow duration curve showing juvenile salmonid passage performance at Piazza, Jan through June

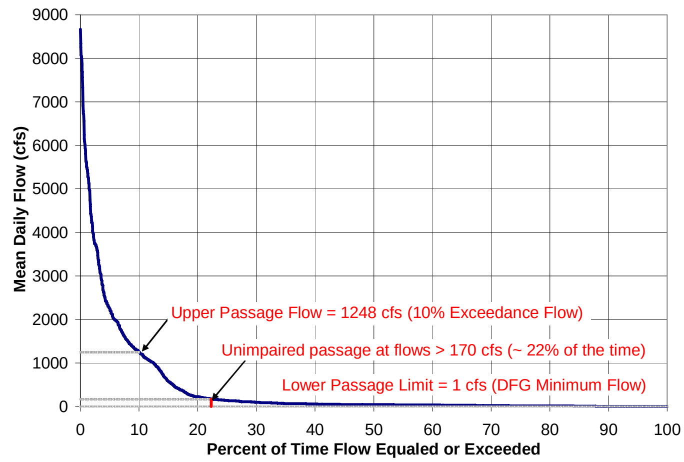


Figure 5-73. Longitudinal profile for Fine Road Bridge

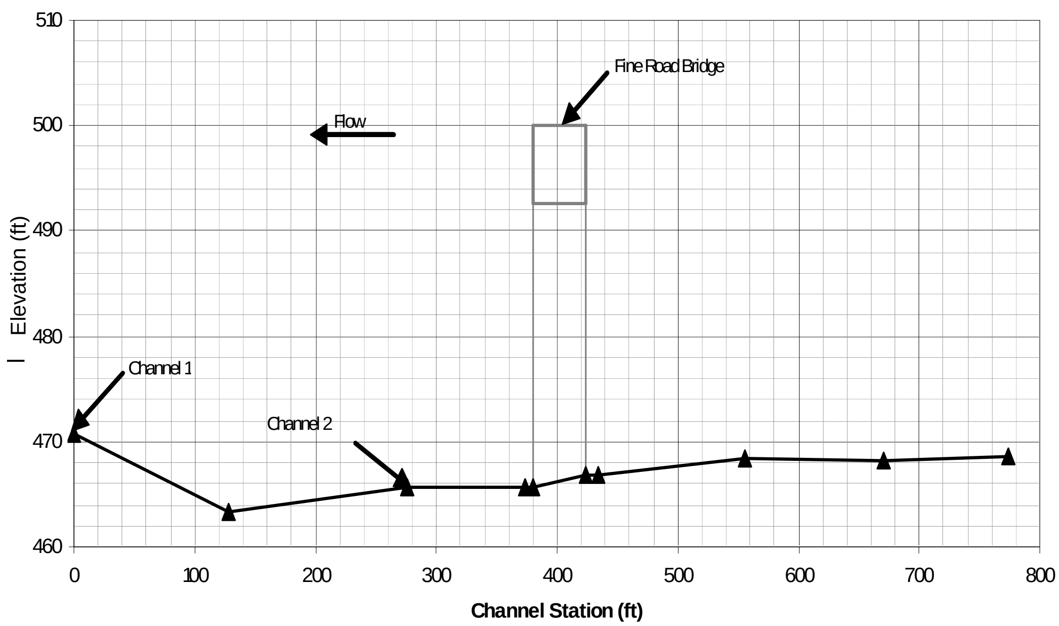


Figure 5-74. Depth curves for Fine Road Bridge

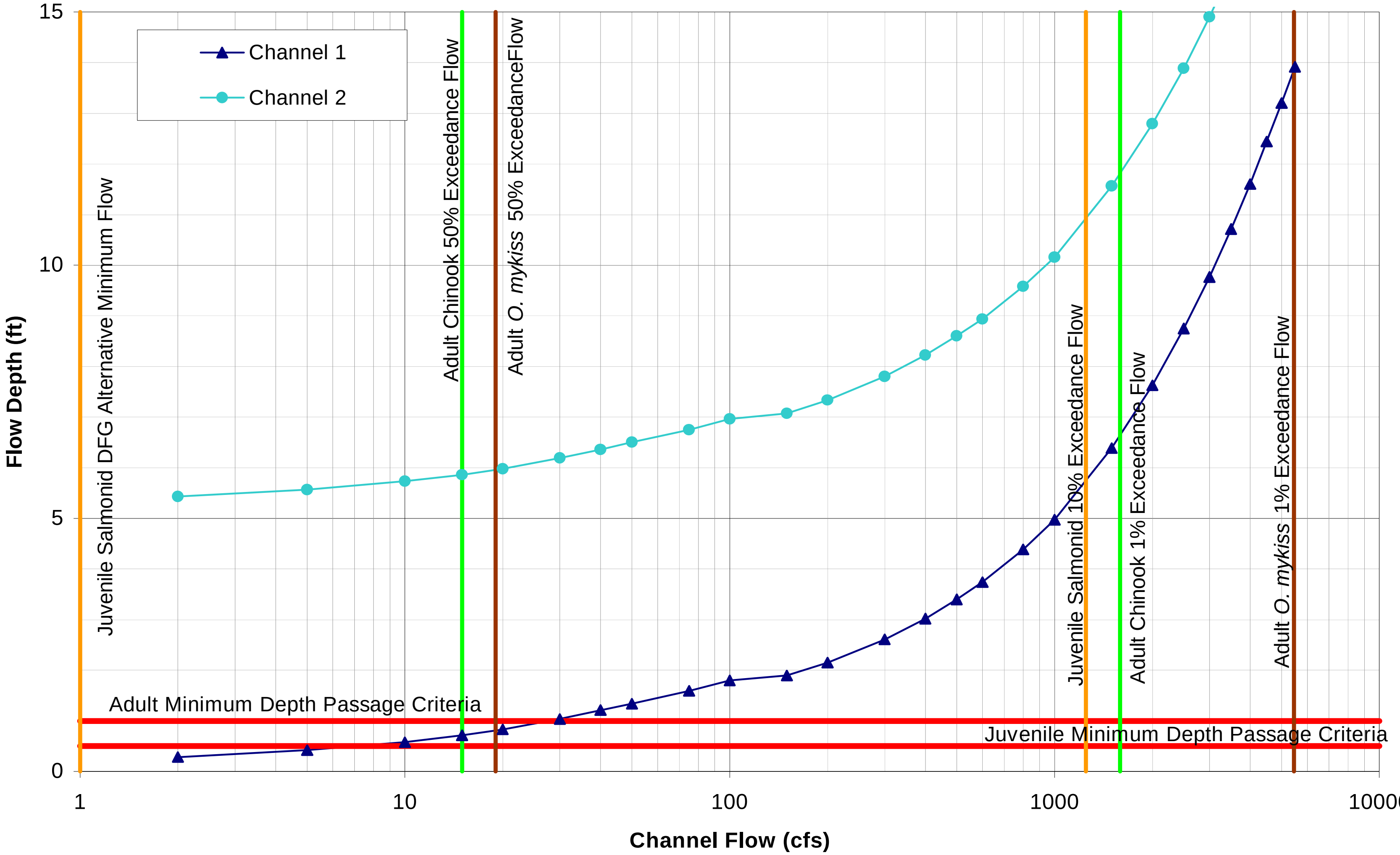


Figure 5-75. Velocity curves for Fine Road Bridge

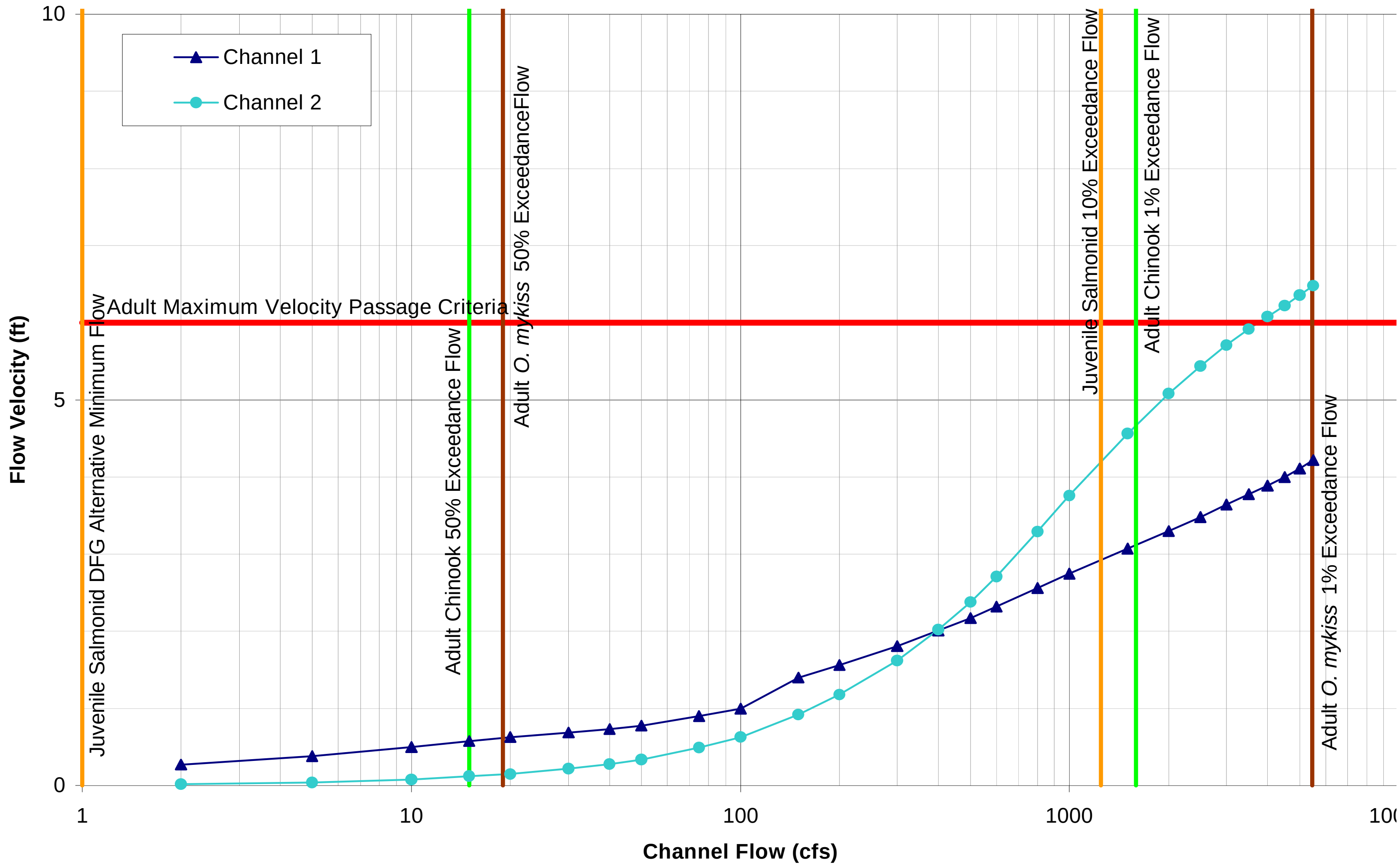


Figure 5-76. Mormon Slough upstream of MSRR Crossing flow duration curve showing adult Chinook passage performance at Fine Road Bridge, Sep through Dec

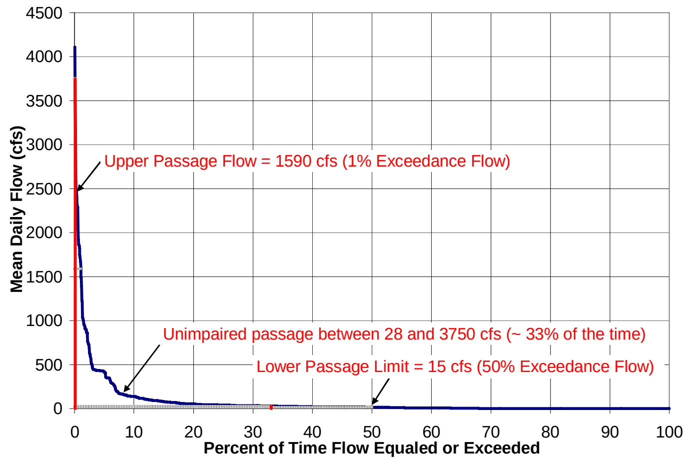


Figure 5-77. Mormon Slough upstream of MSRR Crossing flow duration curve showing adult O. mykiss passage performance at Fine Road Bridge, Oct through Mar

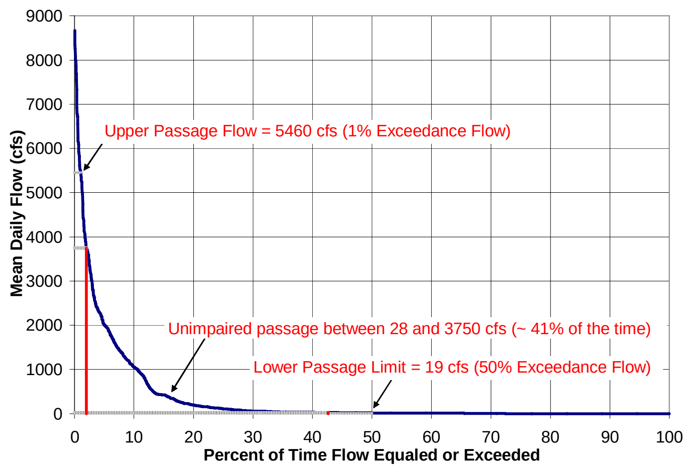


Figure 5-78. Mormon Slough upstream of MSRR Crossing flow duration curve showing juvenile salmonid passage performance at Fine Road Bridge, Jan through June

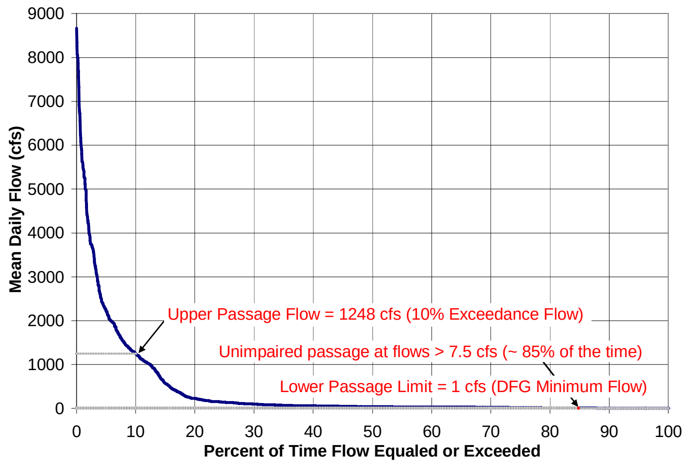


Figure 5-79. Longitudinal profile at Gotelli Low-flow Road Crossing

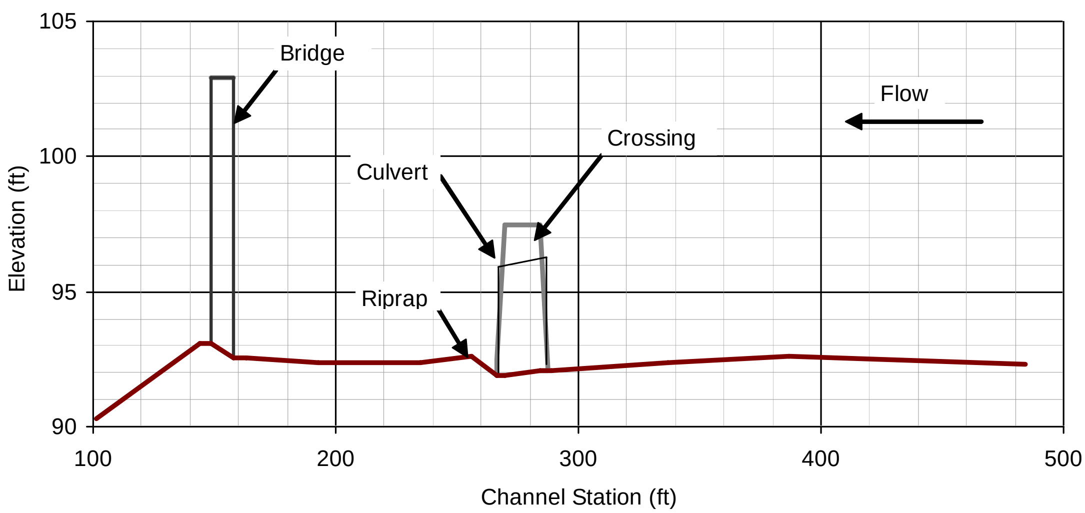


Figure 5-80. Depth curves for Gotelli Low-flow Road Crossing

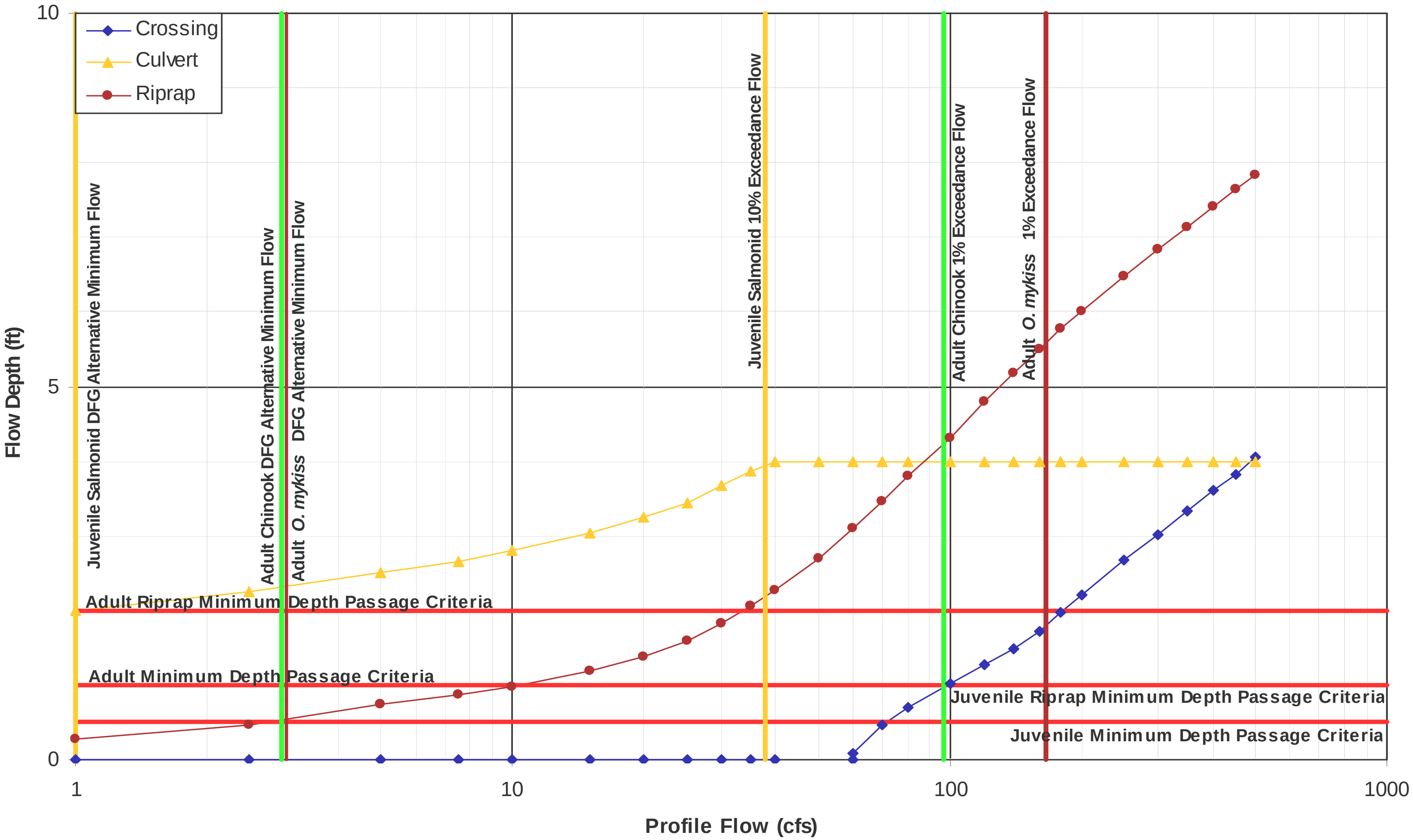


Figure 5-81. Velocity curves for Gotelli Low-flow Road Crossing

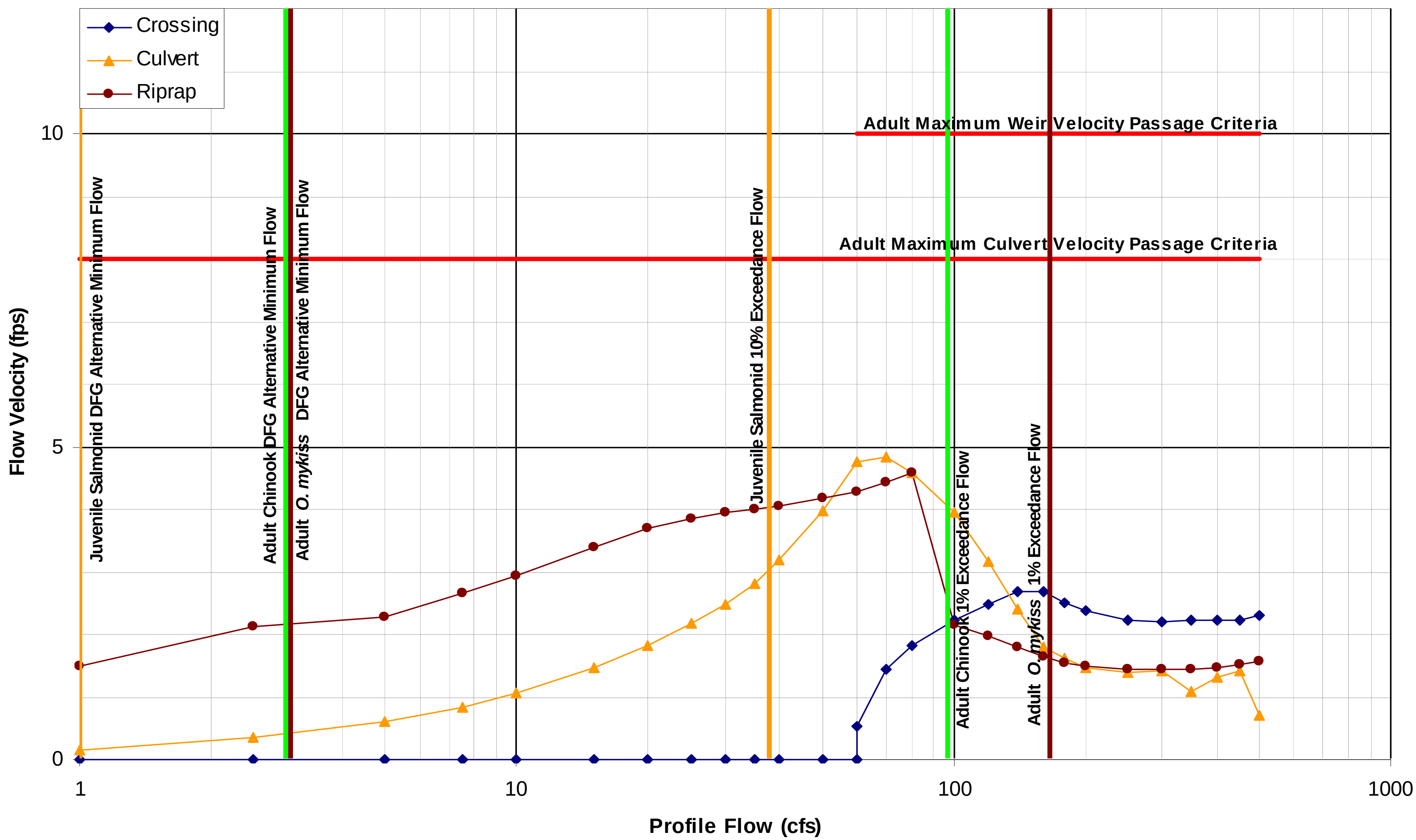


Figure 5-82. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at Gotelli, Sep through Dec

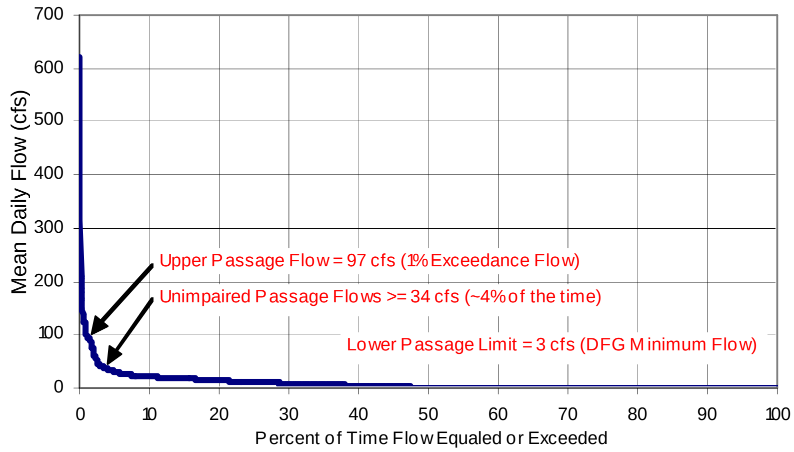


Figure 5-83. Calaveras River Headworks to SDC flow duration curve showing adult O.mykiss passage performance at Gotelli, Oct through Mar

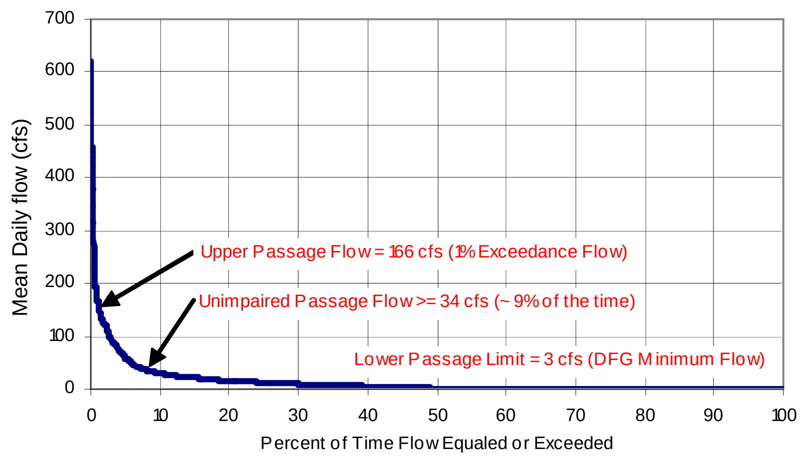


Figure 5-84. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Gotelli, Jan through June

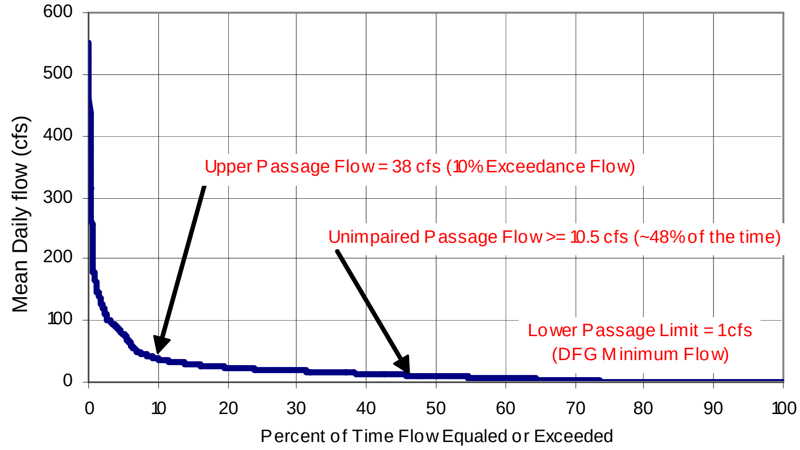


Figure 5-85. Longitudinal profile at McAllen Road Bridge

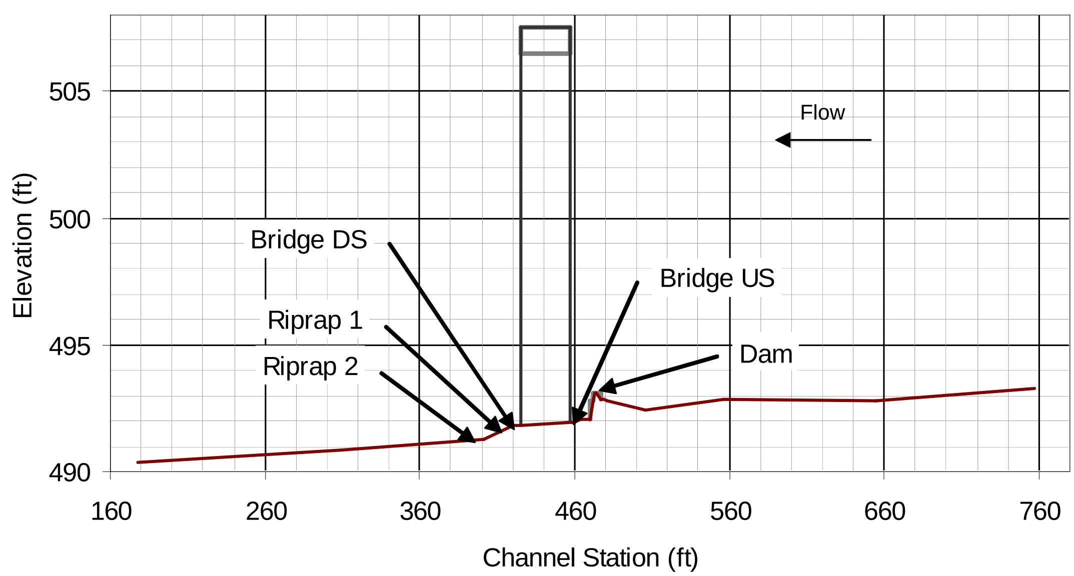


Figure 5-86. Depth curves for McAllen Road Bridge

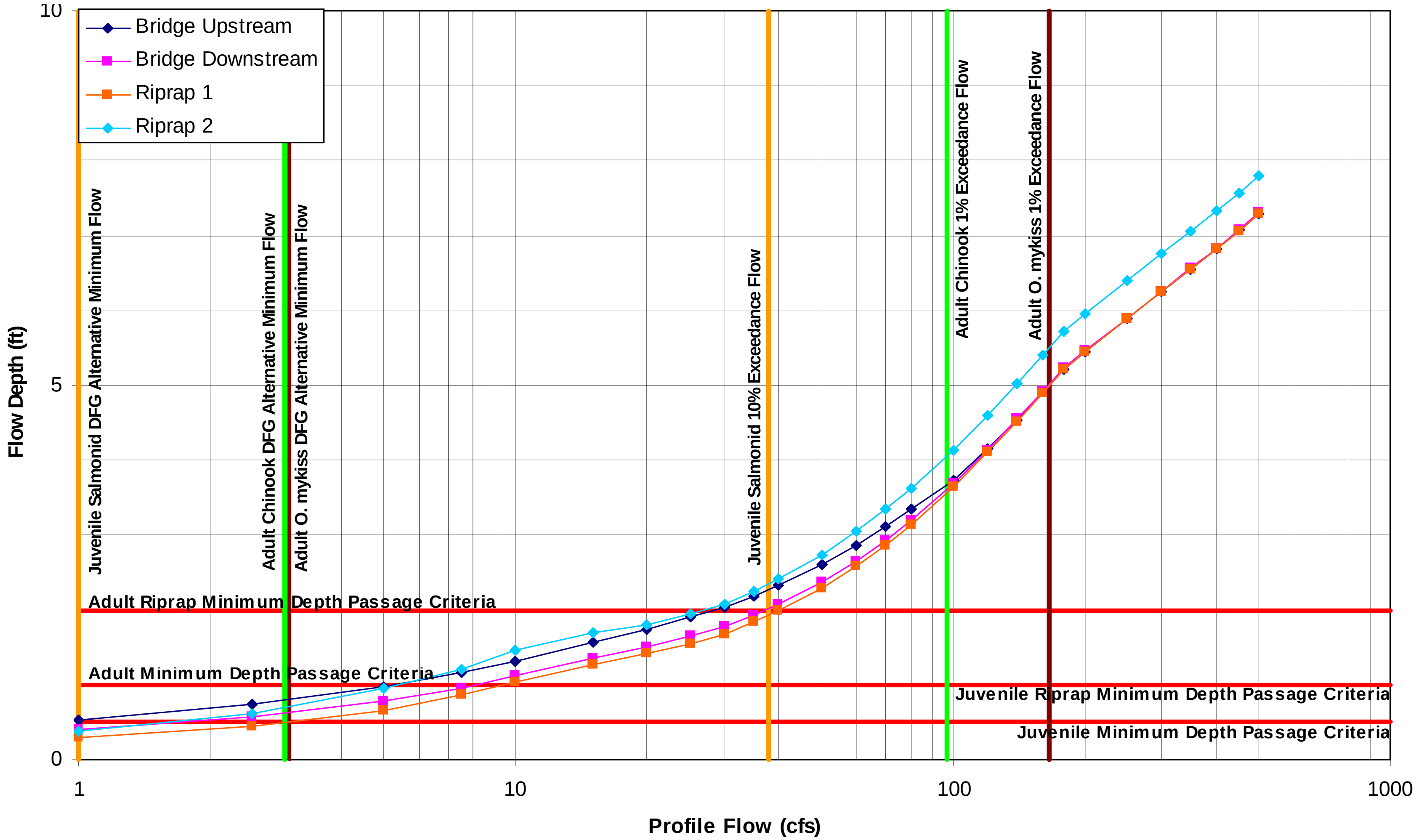


Figure 5-87. Velocity curves for McAllen Road Bridge

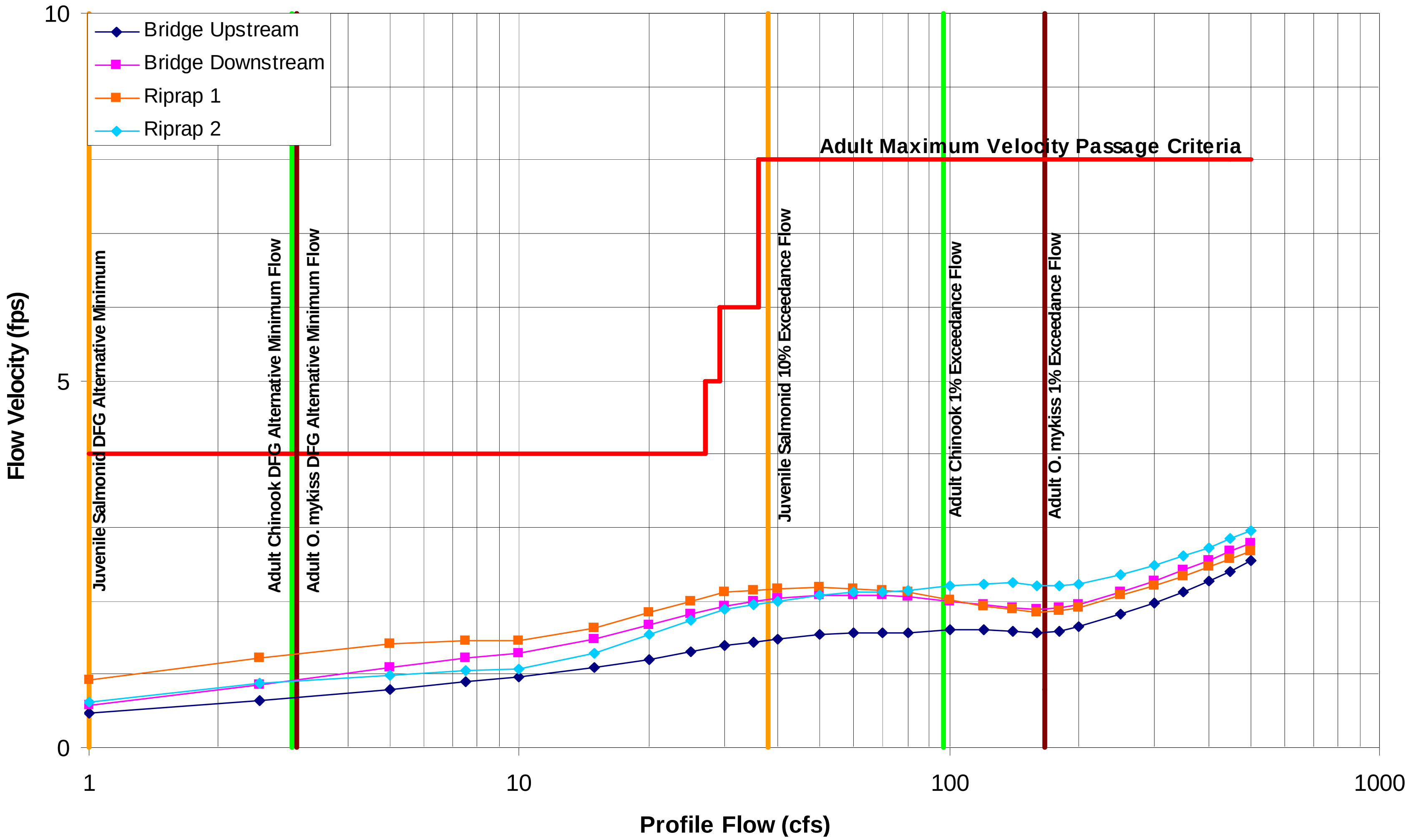


Figure 5-88. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at McAllen Road Bridge, Sep through Dec

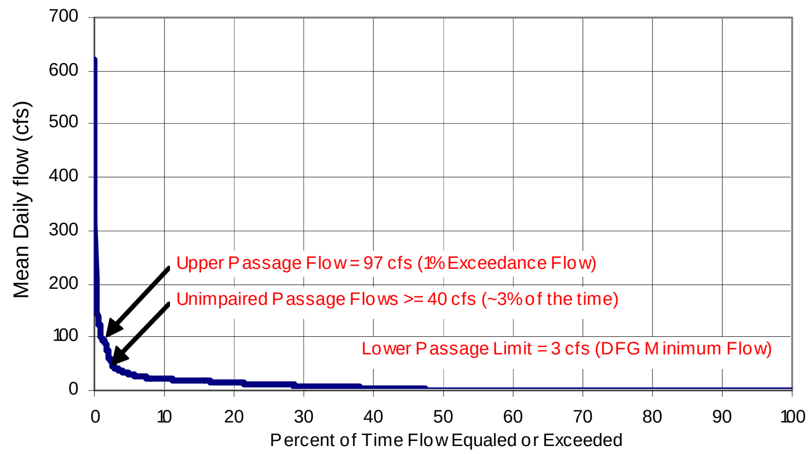


Figure 5-89. Calaveras River Headworks to SDC flow duration curve showing adult O. mykiss passage performance at McAllen Road Bridge, Oct through Mar

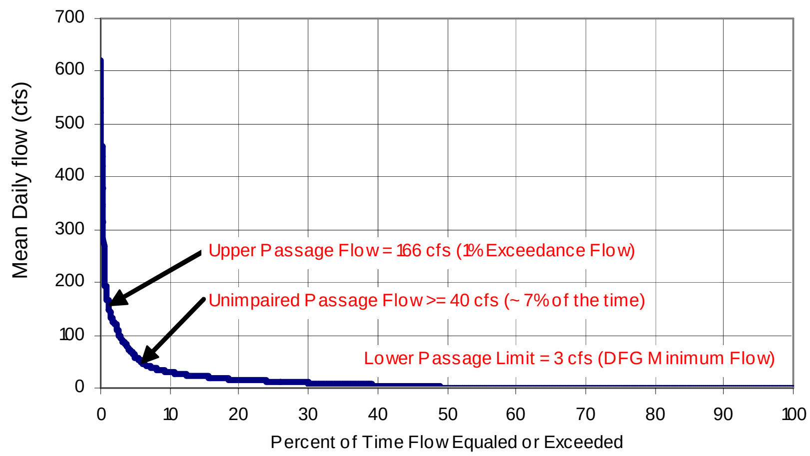


Figure 5-90. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at McAllen Road Bridge, Jan through June

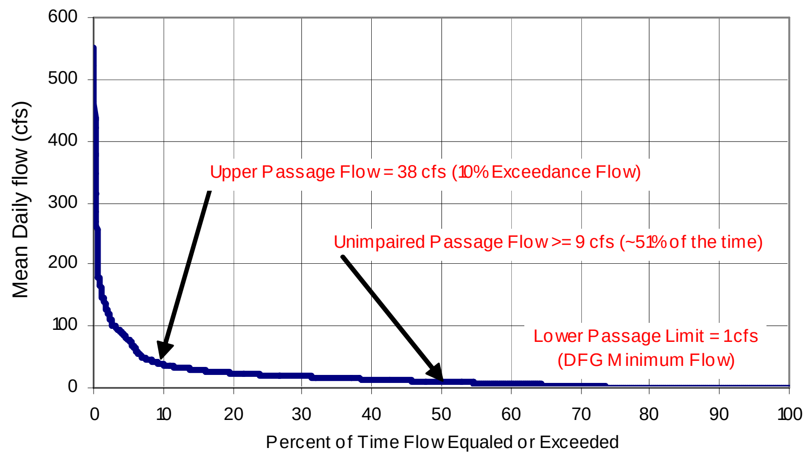


Figure 5-91. Longitudinal profile at McAllen Flashboard Dam

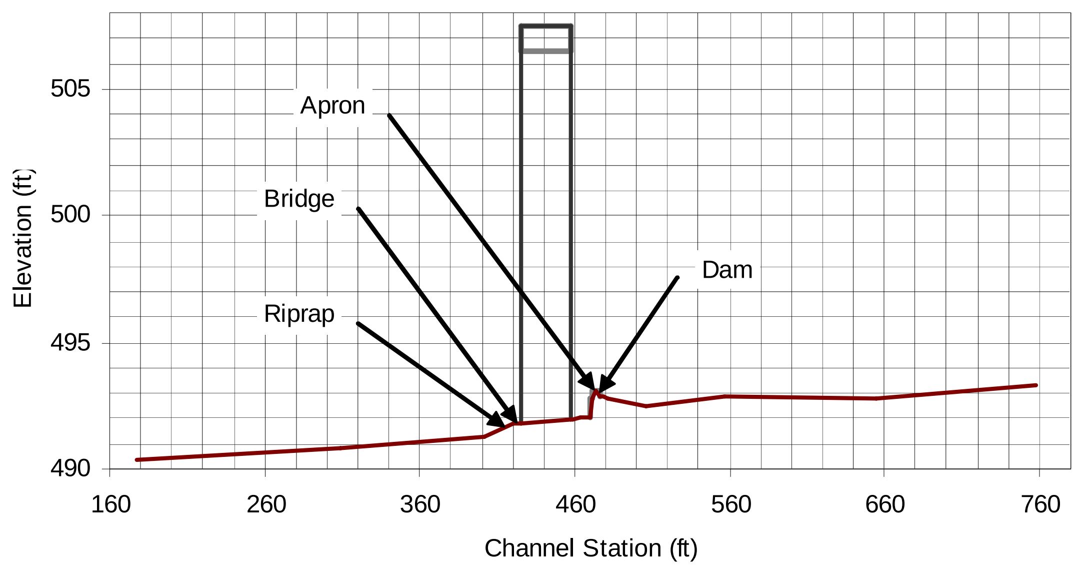


Figure 5-92. Depth curves for McAllen Flashboard Dam

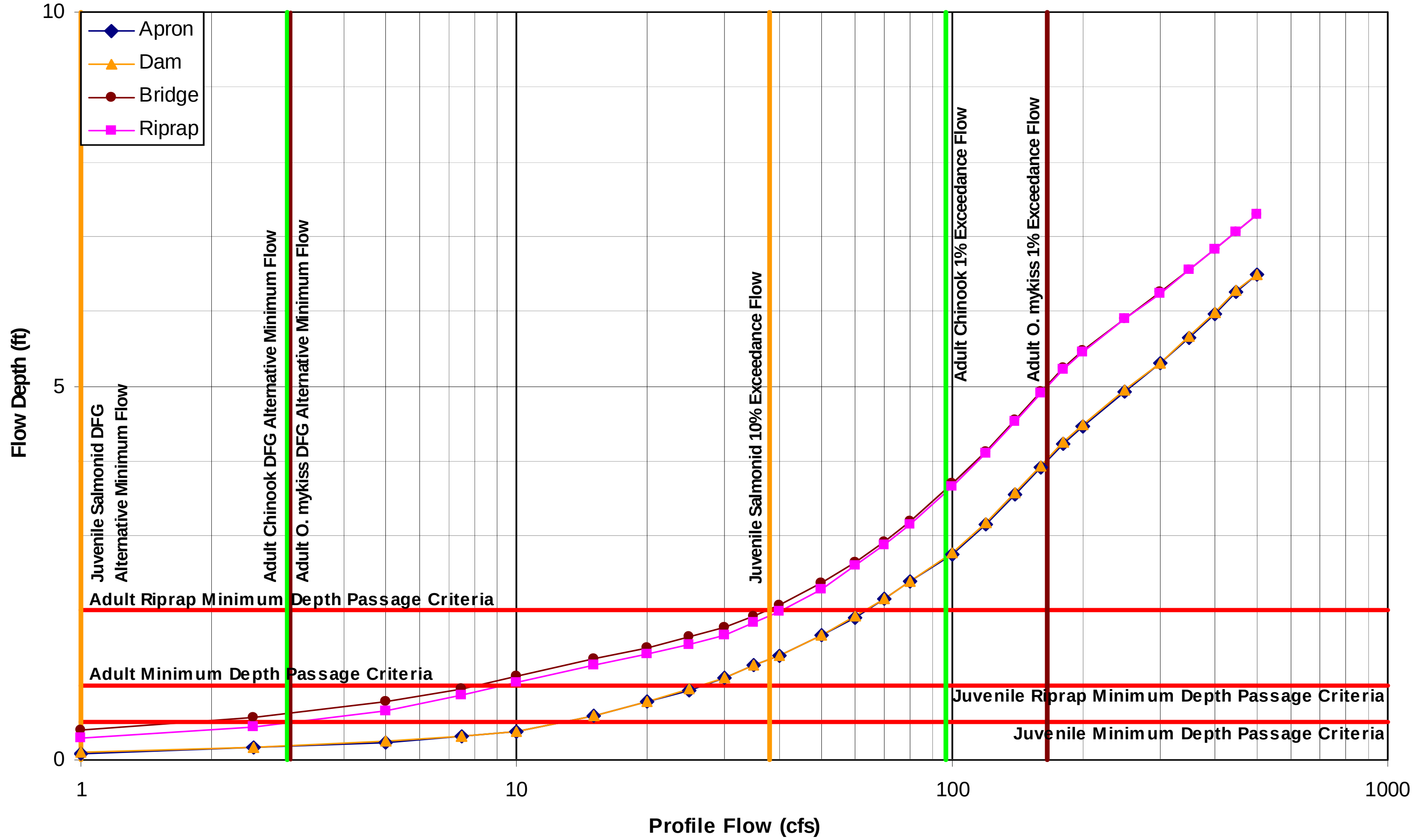


Figure 5-93. Velocity curves for McAllen Flashboard Dam

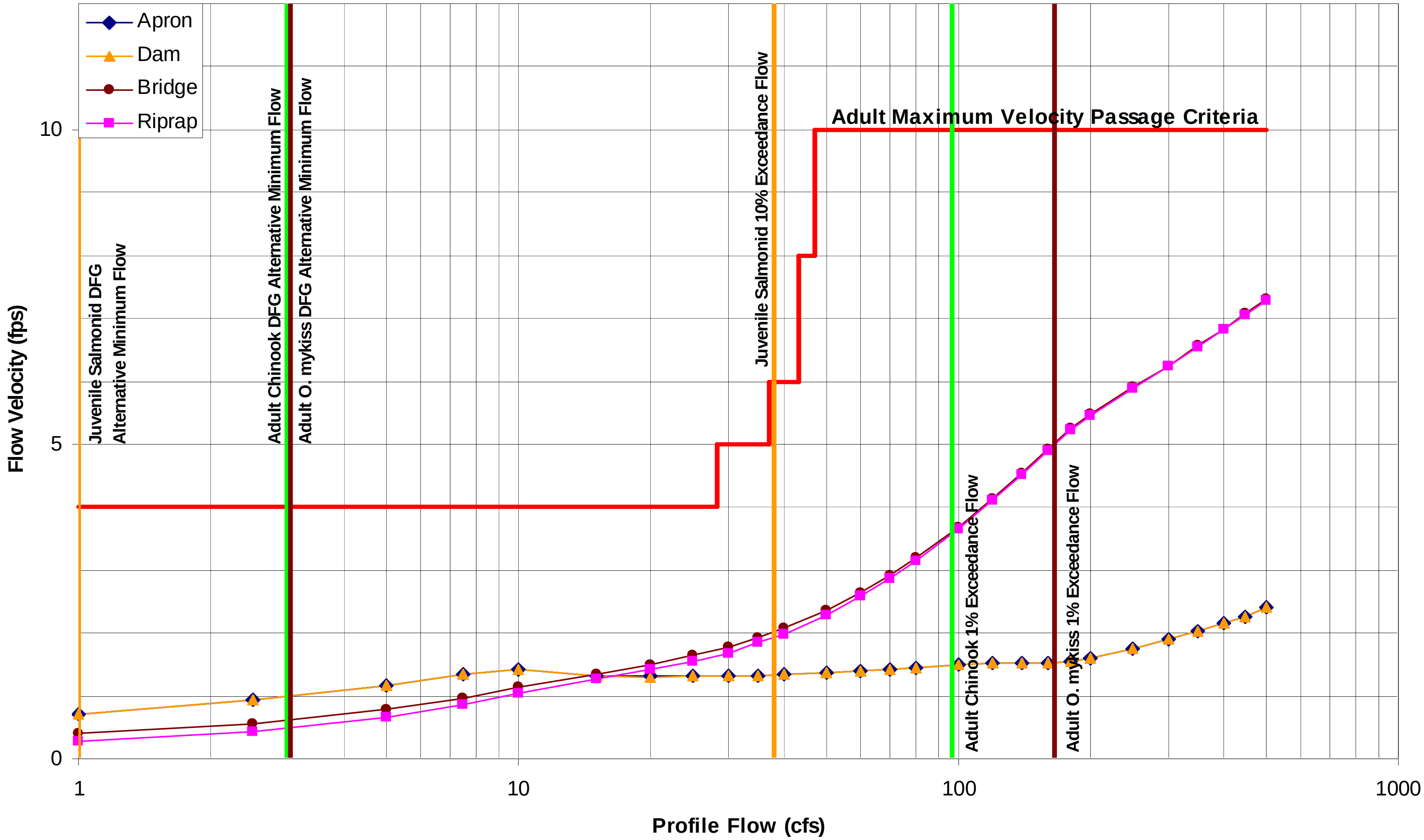


Figure 5-94. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at McAllen Flashboard Dam, Sep through Dec

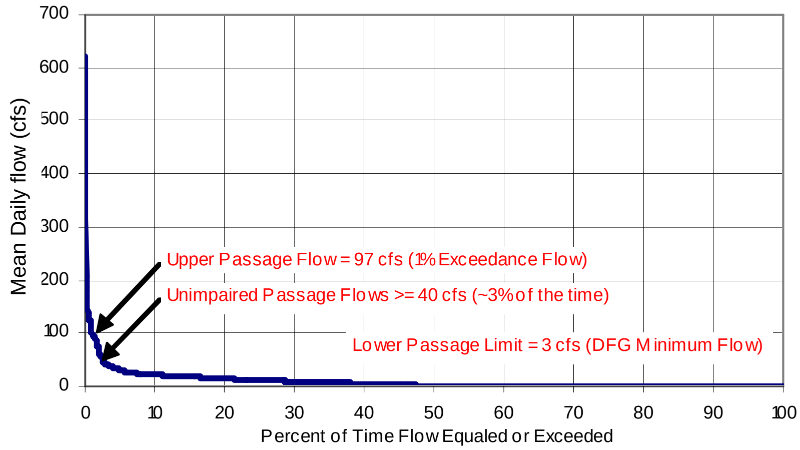


Figure 5-95. Calaveras River Headworks to SDC flow duration curve showing adult *O. mykiss* passage performance at McAllen Flashboard Dam, Oct through Mar

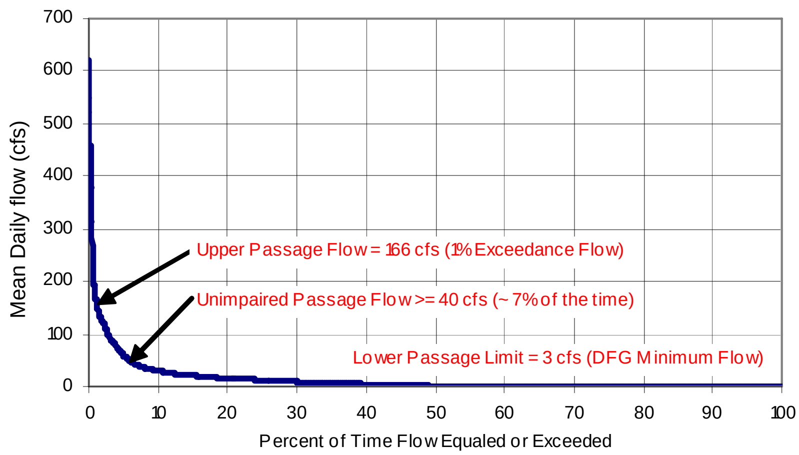


Figure 5-96. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at McAllen Flashboard Dam, Jan through June

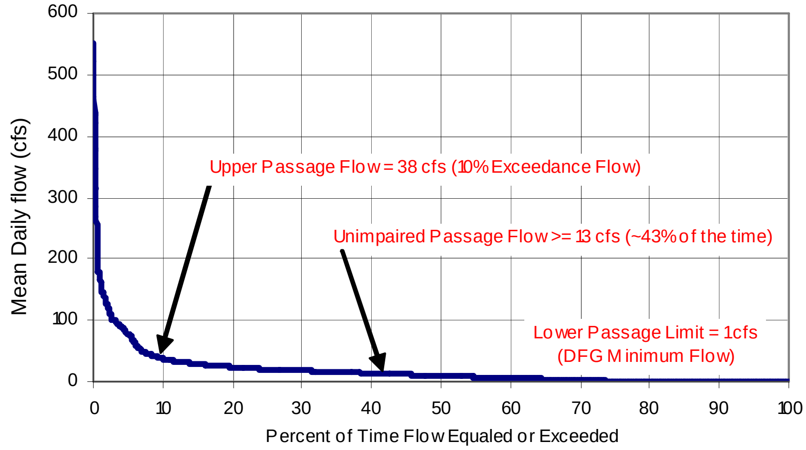


Figure 5-97. Longitudinal profile at Cherryland Flashboard Dam

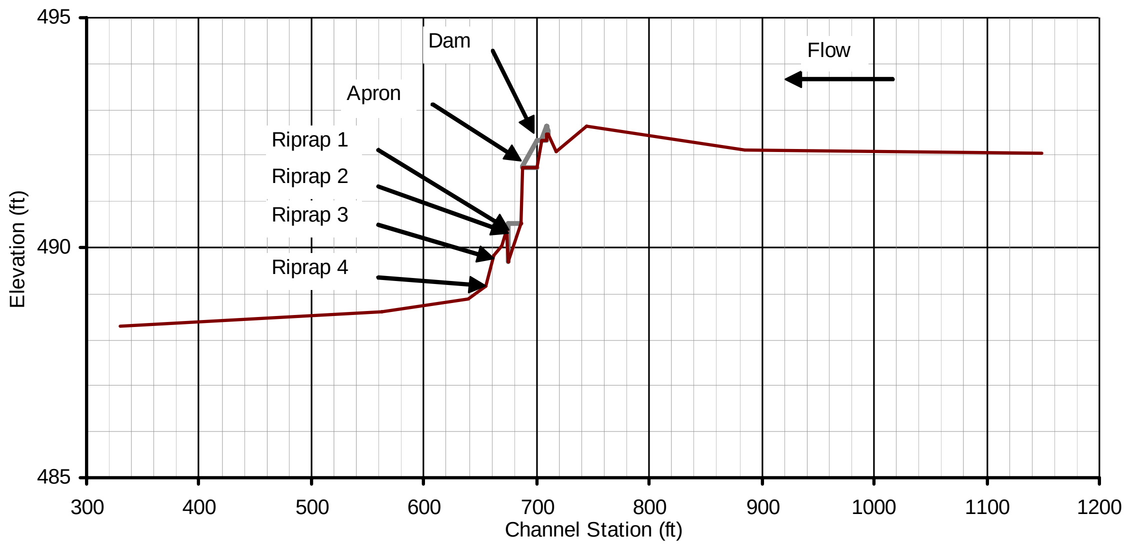


Figure 5-98. Depth curves for Cherryland Flashboard Dam

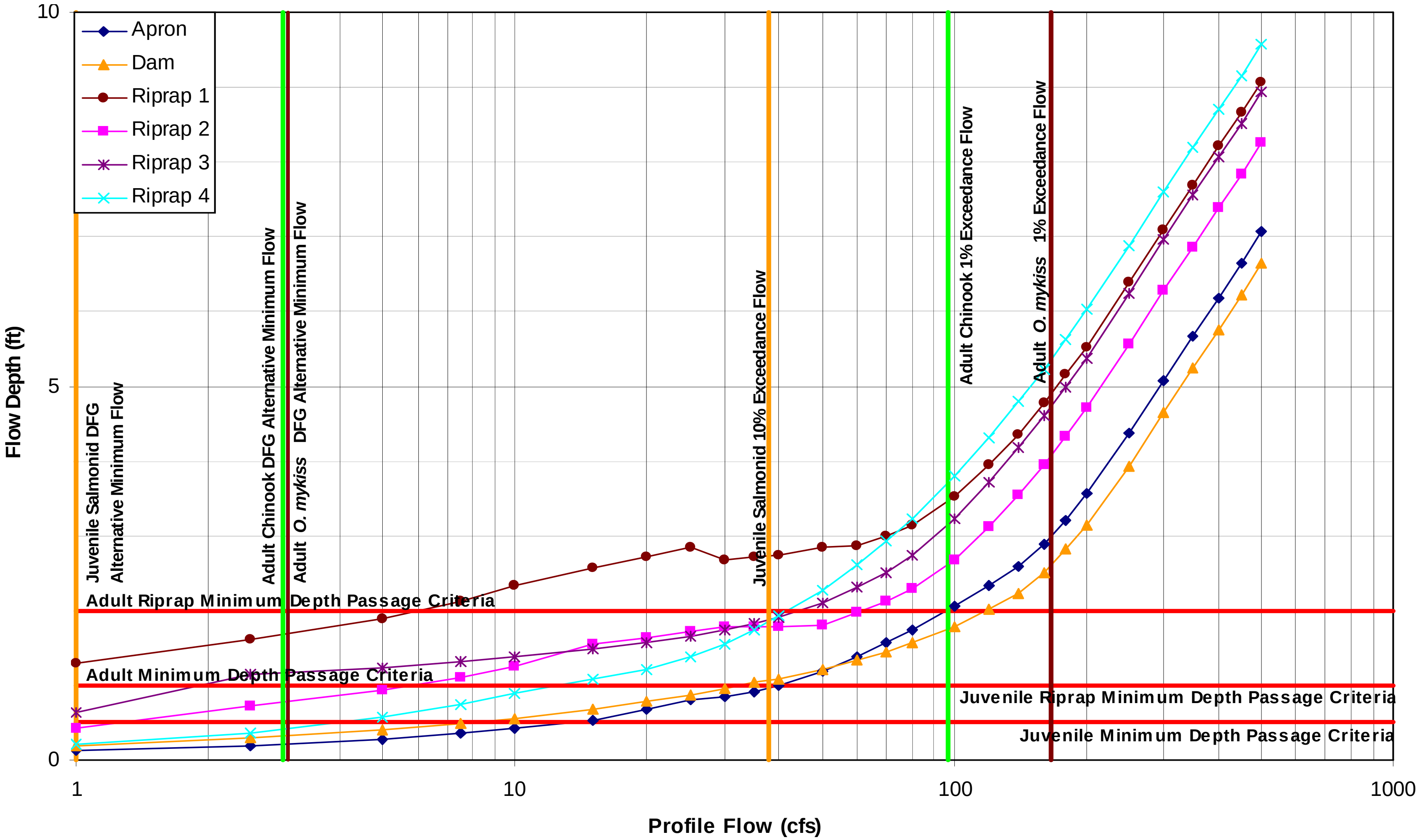


Figure 5-99. Velocity curves for Cherryland Flashboard Dam

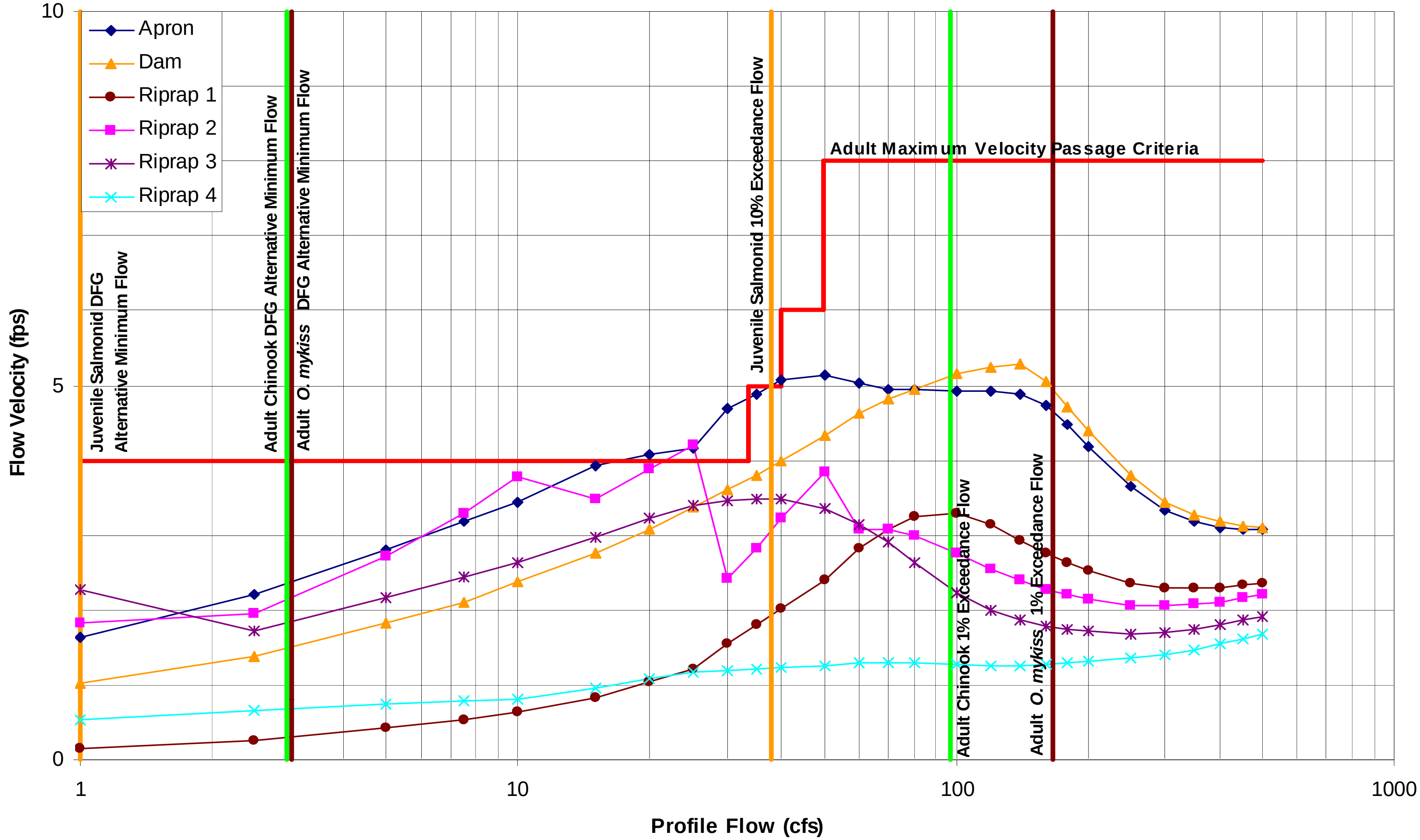


Figure 5-100. Calaveras River Headworks to SDC flow duration curve showing adult Chinook passage performance at Cherryland FBD, Sep through Dec

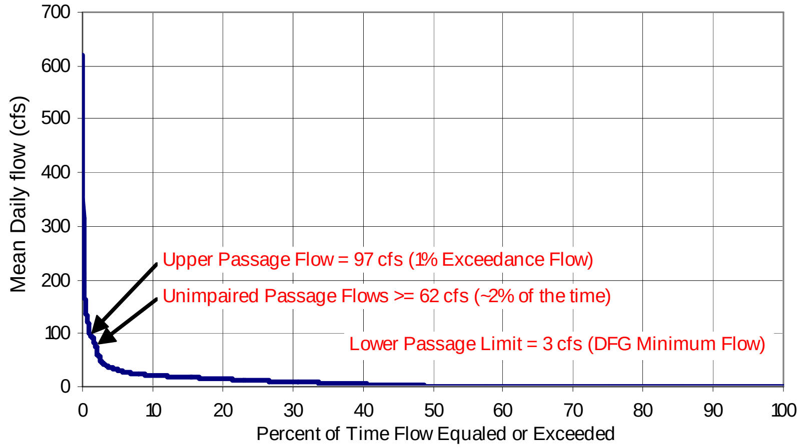


Figure 5-101. Calaveras River Headworks to SDC flow duration curve showing adult O. mykiss passage performance at Cherryland FBD, Oct through Mar

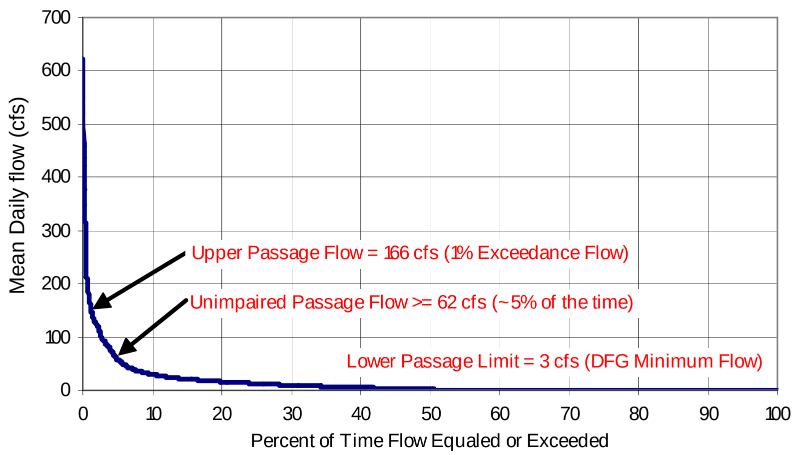
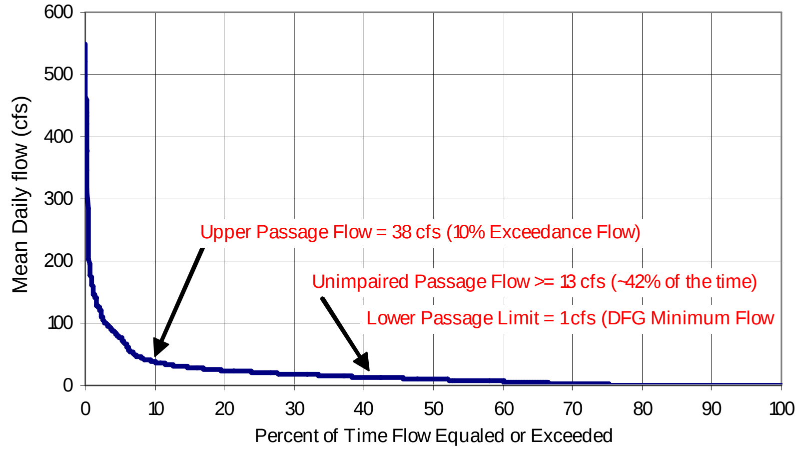


Figure 5-102. Calaveras River Headworks to SDC flow duration curve showing juvenile salmonid passage performance at Cherryland FBD, Jan through June



Chapter 5 Fish Passage Evaluation Results

List of Tables

Table 5-1. Structure scoring

Structure name	Channel	Score	Notes
Clements Road Flashboard Dam (boards removed)	Calaveras River	7	Modeled 2004
Bellota Weir (boards removed)	Mormon Slough	6	
Cherryland Flashboard Dam (boards removed)	Calaveras River	6	Modeled 2005
Budiselich Flashboard Dam (boards removed)	Stockton Diverting Canal	5	Modeled 2004
Calaveras Headworks	Calaveras River	5	
Caprini Low Flow Road Crossing	Mormon Slough	5	Modeled 2004
Central California Traction Railroad Bridge	Stockton Diverting Canal	5	Modeled 2004
Hogan Low Flow Road Crossing	Mormon Slough	5	Modeled 2004
Hosie Low Flow Road Crossing	Mormon Slough	5	Modeled 2004
Mormon Slough Railroad Bridge	Mormon Slough	5	Modeled 2005
Watkins Low Flow Road Crossing	Mormon Slough	5	Modeled 2004
Bonomo Flashboard Dam (boards removed)	Mormon Slough	4	
Fujinaka Low Flow Road Crossing	Mormon Slough	4	Modeled 2005
McGurk Earth Dam	Calaveras River	4	
McGurk Low Flow Road Crossing	Calaveras River	4	
Panella Flashboard Dam (boards removed)	Mormon Slough	4	
Prato Flashboard Dam (boards removed)	Mormon Slough	4	
Avansino Flashboard Dam (boards removed)	Mormon Slough	3	
Deteriorated Low Flow Road Crossing	Calaveras River	3	
Fine Road Flashboard Dam (boards removed)	Mormon Slough	3	
Gotelli Low Flow Road Crossing (RM 6.2)	Calaveras River	3	Modeled 2005
Gotelli Low Flow Road Crossing (RM 35.3)	Calaveras River	3	
Hosie Flashboard Dam (boards removed)	Mormon Slough	3	
Highway 99 Bridge	Calaveras River	3	
Lavaggi Flashboard Dam	Mormon Slough	3	Modeled 2005
McAllen Road Bridge (boards removed)	Calaveras River	3	Modeled 2005
McClean Flashboard Dam	Mormon Slough	3	
New Hogan Dam Road Bridge	Calaveras River	3	
Old Dog Low Flow Road Crossing	Calaveras River	3	
Old Dog Ranch Bridge	Calaveras River	3	
Old Wooden Bridge	Calaveras River	3	
Pershing Avenue Bridge	Calaveras River	3	
Piazza Flashboard Dam (boards removed)	Mormon Slough	3	Modeled 2005
Wilsons Low Flow Road Crossing	Calaveras River	3	
Concrete Slabs (remnant bridge)	Mormon Slough	2	
Guernsey Bridge	Calaveras River	2	
Highway 26 Flashboard Dam (boards removed)	Mormon Slough	2	
McAllen Flashboard Dam (boards removed)	Calaveras River	2	Modeled 2005
Old DWR Stream Gage Weir	Calaveras River	2	
Tully Flashboard Dam (boards removed)	Calaveras River	2	
Botsford Bridge #2	Calaveras River	1	

Structure name	Channel	Score	Notes
Eight Mile Flashboard Dam (boards removed)	Calaveras River	1	
Main Street Flashboard Dam (boards removed)	Mormon Slough	1	
Murphy Flashboard Dam (boards removed)	Calaveras River	1	Modeled 2004
Partial concrete structure near Pacific Avenue Bridge	Calaveras River	1	
Pezzi Flashboard Dam (boards removed)	Calaveras River	1	
Rubble Dam above Bellota Weir	Calaveras River	1	
Solari Flashboard Dam (boards removed)	Calaveras River	1	
Alpine Road Bridge	Calaveras River	0	
Ashley Lane Bridge	Calaveras River	0	
Bridge near Panella Flashboard Dam	Mormon Slough	0	
Cherokee Bridge	Stockton Diverting Canal	0	
Chestnut Hill Road Bridge	Calaveras River	0	
Copperopolis Road Bridge	Mormon Slough	0	
De Martini Lane Bridge	Calaveras River	0	
De Martini Wood Bridge	Calaveras River	0	
Duncan Road Bridge #1	Calaveras River	0	
Duncan Road Bridge	Mormon Slough	0	
Eight Mile Road Bridge	Calaveras River	0	
El Dorado Street Bridge	Calaveras River	0	
Escalon Belota Bridge	Mormon Slough	0	
Fine Road Bridge	Mormon Slough	0	Modeled 2005
Flood Road Bridge	Mormon Slough	0	
Gotelli #1 Flashboard Dam (boards removed)	Calaveras River	0	
Gotelli Bridge #1	Calaveras River	0	
Gotelli Bridge #2	Calaveras River	0	
Highway 88 Bridge	Calaveras River	0	
Houston Bridge	Calaveras River	0	
Highway 26 Bridge	Calaveras River	0	
Highway 26 Bridge	Stockton Diverting Canal	0	
Highway 99 Bridge	Stockton Diverting Canal	0	
Interstate 5 Bridge	Calaveras River	0	
Jack Tone Road Bridge	Calaveras River	0	
Jack Tone Road foot bridge	Calaveras River	0	
Jack Tone Road Bridge	Mormon Slough	0	
Messick Road Bridge	Calaveras River	0	
Milton Road Bridge	Calaveras River	0	
Milton Road Bridge	Mormon Slough	0	
Pacific Avenue Bridge	Calaveras River	0	
Pedestrian Bridge adjacent to Highway 99	Calaveras River	0	
Pedestrian bridge near Railroad Bridge #1	Calaveras River	0	
Pelota #1 Bridge	Calaveras River	0	

Structure name	Channel	Score	Notes
Pezzi Road Bridge	Calaveras River	0	
Podesta #1 bridge	Calaveras River	0	
Rosa Bridge	Calaveras River	0	
Railroad Bridge #1	Calaveras River	0	
Railroad Bridge #2	Calaveras River	0	
Railroad Bridge near Leonardini Road	Calaveras River	0	
Shelton Road Bridge	Calaveras River	0	
Solari Ranch Road Bridge	Calaveras River	0	
Southern Pacific Railroad Bridge	Stockton Diverting Canal	0	
Stockton Terminal and Eastern Railroad Bridge	Stockton Diverting Canal	0	
Tully Bridge	Calaveras River	0	
Waterloo Bridge	Stockton Diverting Canal	0	
West Lane Bridge	Calaveras River	0	
Wilson Way Bridge	Stockton Diverting Canal	0	
Wooden bridge west of Wilson Way	Stockton Diverting Canal	0	
Duncan Road driveway bridge	Calaveras River	No Score	Access denied
Williams Low Flow Road Crossing	Calaveras River	No Score	Access denied

Table 5-2. Scoring of flashboard dams with boards in place

Structure name	Channel	Score	Notes
Cherryland Flashboard Dam	Calaveras River	9	
Panella Flashboard Dam	Mormon Slough	9	
Lavaggi Flashboard Dam	Mormon Slough	9	
McClean Flashboard Dam	Mormon Slough	9	
Prato Flashboard Dam	Mormon Slough	9	
Clements Road Flashboard Dam	Calaveras River	9	
McAllen Flashboard Dam	Calaveras River	8	
Bellota Weir (with flashboard component)[a]	Mormon Slough	8	
Main Street Flashboard Dam	Mormon Slough	6	
Piazza Flashboard Dam	Mormon Slough	6	
Bonomo Flashboard Dam	Mormon Slough	6	
Hosie Flashboard Dam	Mormon Slough	6	
Avansino Flashboard Dam	Mormon Slough	6	
Fine Road Flashboard Dam	Mormon Slough	6	
Hwy 26 FB Flashboard Dam	Mormon Slough	6	
Pezzi Flashboard Dam	Calaveras River	5	
Eight Mile Flashboard Dam	Calaveras River	5	
Tully Flashboard Dam	Calaveras River	5	
Murphy Flashboard Dam	Calaveras River	3	
Solari Flashboard Dam	Calaveras River	No Score	Boards down at site visit, August 2005
Gotelli #1 Flashboard Dam	Calaveras River	No Score	Boards down at site visit, August 2005
Budiselich Flashboard Dam	Stockton Diverting Canal	No Score	Boards down at site visit, June 2004

[a] Bellota Weir has a flashboard component but is not a flashboard dam.

Table 5-3. Grouped bridges on the Calaveras River

Structure	Map ID No.	Channel	Score
McAllen Road Bridge	12	Calaveras River	3
Represents:			
Interstate 5 Bridge	1	Calaveras River	0
Pershing Avenue Bridge	2	Calaveras River	3
Pacific Avenue Bridge Southbound	3	Calaveras River	0
El Dorado Street Bridge	5	Calaveras River	0
Railroad Bridge #2	6	Calaveras River	0
West Lane Bridge	7	Calaveras River	0
Pedestrian Bridge near Railroad Bridge #1	8	Calaveras River	0
Railroad Bridge #1	9	Calaveras River	0
Old Wooden Bridge	10	Calaveras River	3
Pedestrian Bridge adjacent to Highway 99	14	Calaveras River	0
Highway 99 Bridge	15	Calaveras River	3
Railroad Bridge near Leonardini Road	17	Calaveras River	0
Solari Ranch Road Bridge	19	Calaveras River	0
Ashley Lane Bridge	21	Calaveras River	0
Alpine Road Bridge	22	Calaveras River	0
Pezzi Road Bridge	23	Calaveras River	0
Highway 88 Bridge	26	Calaveras River	0
Eight Mile Road Bridge	27	Calaveras River	0
Jack Tone Road Foot Bridge	29	Calaveras River	0
Jack Tone Road Bridge	30	Calaveras River	0
Tully Road Bridge	31	Calaveras River	0
Rosa Bridge	33	Calaveras River	0
Duncan Road Bridge #1	34	Calaveras River	0
Messick Road Bridge	36	Calaveras River	0
Guernsey Bridge	37	Calaveras River	2
Botsford Bridge #2	40	Calaveras River	1
Houston Bridge	41	Calaveras River	0
De Martini Lane Bridge	43	Calaveras River	0
De Martini Wood Bridge	44	Calaveras River	0
Chestnut Hill Road Bridge	45	Calaveras River	0
Podesta #1 Bridge	46	Calaveras River	0
Pelota #1 Bridge	47	Calaveras River	0
Gotelli Bridge #1	49	Calaveras River	0
Gotelli Bridge #2	50	Calaveras River	0
Old Dog Ranch Bridge	56	Calaveras River	3
Shelton Road Bridge	57	Calaveras River	0
New Hogan Dam Road Bridge	62	Calaveras River	3

Table 5-4. Grouped bridges on Mormon Slough and Stockton Diverting Canal

Structure name	Map ID No.	Channel	Score
Fine Road Bridge	95	Mormon Slough	0
Represents:			
Wooden Bridge west of Wilson Way	63	Stockton Diverting Canal	0
Wilson Way Bridge	64	Stockton Diverting Canal	0
Cherokee Road Bridge	66	Stockton Diverting Canal	0
Waterloo Bridge	67	Stockton Diverting Canal	0
Highway 99 Northbound Bridge - Stockton Diverting Canal	68	Stockton Diverting Canal	0
Stockton Terminal and Eastern Railroad Bridge	70	Stockton Diverting Canal	0
Highway 26 Bridge	71	Stockton Diverting Canal	0
Southern Pacific Railroad Bridge	72	Stockton Diverting Canal	0
Bridge near Panella Flashboard Dam	75	Mormon Slough	0
Jack Tone Road Bridge	78	Mormon Slough	0
Copperopolis Road Bridge	82	Mormon Slough	0
Duncan Road Bridge	85	Mormon Slough	0
Milton Road Bridge	87	Mormon Slough	0
Flood Road Bridge	92	Mormon Slough	0
Escalon Bellota Bridge	98	Mormon Slough	0

Table 5-5. Ungrouped bridges

Structure name	Map ID No.	Channel	Score
Mormon Slough Railroad Bridge	84	Mormon Slough	5
Central California Traction Railroad Bridge	65	Stockton Diverting Canal	5

Table 5-6. Ungrouped bridge not scored

Structure name	Map ID No.	Channel	Score
Duncan Road Driveway Bridge	35	Calaveras River	No score

Table 5-7. Grouped low flow road crossings on the Calaveras River

Structure name	Map ID No.	Channel	Score
Gotelli Low Flow Road Crossing (RM 6.2)	11	Calaveras River	3
Represents:			
Old Dog Low Flow Road Crossing	55	Calaveras River	3
Wilsons Low Flow Road Crossing	54	Calaveras River	3
Gotelli Low Flow Road Crossing (RM 35.3)	60	Calaveras River	3

Table 5-8. Grouped low flow road crossings with aprons

Structure name	Map ID No.	Channel	Score
Caprini Low Flow Road Crossing	76	Mormon Slough	5
Represents:			
McGurk Low Flow Road Crossing	53	Upper Calaveras	4

Table 5-9. Ungrouped low flow road crossings

Structure name	Map ID No.	Channel	Score
Hosie Low Flow Road Crossing	90	Mormon Slough	5
Watkins Low Flow Road Crossing	97	Mormon Slough	5
Fujinaka Low Flow Road Crossing	81	Mormon Slough	4
Hogan Low Flow Road Crossing	79	Mormon Slough	5

Table 5-10. Ungrouped low flow road crossings not scored

Structure name	Map ID No.	Channel	Score
Williams Low Flow Road Crossing	58	Upper Calaveras	No score

Table 5-11. Scored permanent dams and weirs

Structure	Map ID No.	Channel	Score
Bellota Weir	99	Mormon Slough	6
Calaveras Headworks	51	Calaveras River	5
McGurk Earth Dam	52	Upper Calaveras	4
Old DWR Stream Gage Weir	18	Calaveras River	2
Concrete slabs (remnant bridge)	89	Mormon Slough	2
Partial concrete structure near Pacific Avenue Bridge	4	Calaveras River	1
Rubble dam above Bellota	61	Upper Calaveras	1

Table 5-12. Grouped flashboard dams (boards removed) with trapezoidal cross sections on the Calaveras River

Structure name	Map ID No.	Channel	Score
McAllen Flashboard Dam	13	Calaveras River	2
Represents			
Tully Flashboard Dam	32	Calaveras River	2
Eight Mile Flashboard Dam	28	Calaveras River	1
Solari Flashboard Dam	20	Calaveras River	1
Gotelli #1 Flashboard Dam	28	Calaveras River	0

Table 5-13. Grouped flashboard dams with rectangular cross sections on the Calaveras River

Structure name	Map ID No.	Channel	Score
Murphy Flashboard Dam	25	Calaveras River	1
Represents:			
Pezzi Flashboard Dam	24	Calaveras River	1

Table 5-14. Grouped flashboard dams (boards removed) downstream of Potter Creek on Mormon Slough

Structure name	Map ID No.	Channel	Score
Lavaggi Flashboard Dam	77	Mormon Slough	3
Represents:			
Main Street Flashboard Dam	73	Mormon Slough	1
Panella Flashboard Dam	74	Mormon Slough	3
McClean Flashboard Dam	80	Mormon Slough	3
Prato Flashboard Dam	83	Mormon Slough	3

Table 5-15. Grouped flashboard dams (board removed) upstream of Potter Creek on Mormon Slough

Structure	Map ID No.	Channel	Score
Piazza Flashboard Dam	86	Mormon Slough	3
Represents:			
Bonomo Flashboard Dam	88	Mormon Slough	3
Hosie Flashboard Dam	91	Mormon Slough	3
Avansino Flashboard Dam	93	Mormon Slough	3
Fine Road Flashboard Dam	95	Mormon Slough	3
Highway 26 Flashboard Dam	96	Mormon Slough	2

Table 5-16. Ungrouped flashboard dams (boards removed)

Structure name	Map ID No.	Channel	Score
Clements Road Flashboard Dam	38	Calaveras River	7
Cherryland Flashboard Dam	16	Calaveras River	6
Budiselich Flashboard Dam	70	Stockton Diverting Canal	5

Table 5-17. Percent of time with unimpaired passage at modeled structures

Modeled Structure	Phase I	Unimpaired Passage – % of Time		
	Score	Chinook	*O. mykiss*	Juveniles
Clements Flashboard Dam	7	2	4	15
Cherryland Flashboard Dam	6	2	5	42
Budiselich Flashboard Dam	5	2	12	18
Caprini Low Flow Crossing	5	2	12	21
Central California Railroad Bridge	5	5	18	47
Hosie Low Flow Crossing	5	6	17	28
Mormon Slough Railroad Bridge	5	27	30	85
Watkins Low Flow Crossing	5	5	16	27
Fujinaka Low-flow Road Crossing	4	16	34	62
Hogan Low-flow Road Crossing	4	10	29	56
Gotelli Low-flow Road Crossing (RM 6.2)	3	4	9	48
Lavaggi Flashboard Dam	3	8	25	34
McAllen Road Bridge	3	3	7	51
Piazza Flashboard Dam	3	6	17	22
McAllen Flashboard Dam	2	3	7	43
Murphy Flashboard Dam	1	5	10	55
Fine Road Bridge	0	33	41	85

Table 5-18. Adult Chinook passage performance at Central California Traction Railroad Crossing

Model	Depth (ft)					Velocity (ft/s)				
Flow (cfs)	Riprap 2	Riprap 1	Flume 2*	Flume 1*	Weir*	Riprap 2	Riprap 1	Flume 2*	Flume 1*	Weir*
2	0.76	0.74	1.38	0.19	0.03	1.43	0.65	2.19	2.02	0
3	0.85	0.79	1.42	0.23	0.03	1.38	0.70	2.47	2.32	0.00
5	1.02	0.89	1.51	0.31	0.03	1.28	0.8	3.03	2.93	0
10	1.15	1.02	1.68	0.47	0.03	1.26	1.06	3.81	3.75	0
15	1.21	1.1	1.81	0.6	0.03	1.42	1.28	4.36	4.35	0
20	1.26	1.17	1.94	0.72	0.03	1.55	1.48	4.8	4.81	0
30	1.35	1.28	2.16	0.95	0.02	1.71	1.78	5.47	5.45	0
40	1.43	1.38	2.36	1.15	0.02	1.79	2.02	6	5.99	0
50	1.49	1.45	2.5	1.29	0.19	1.9	2.18	6.38	6.33	2.02
75	1.64	1.56	2.71	1.51	0.48	2.1	2.37	6.91	6.78	2.87
100	1.78	1.65	2.84	1.69	0.66	2.18	2.42	7.2	6.91	2.99
150	2	1.81	3.02	1.93	0.87	2.4	2.4	7.59	7.04	3.58
200	2.17	1.96	3.16	2.11	1.02	2.58	2.34	7.89	7.22	4.04
210	2.21	2.00	3.19	2.15	1.06	2.60	2.33	7.95	7.27	4.06
300	2.48	2.25	3.4	2.4	1.33	2.76	2.25	8.34	7.56	4.2
400	2.75	2.51	3.54	2.57	1.56	2.91	2.11	8.62	7.73	4.43
500	3.01	2.76	3.66	2.71	1.7	2.98	1.98	8.83	7.89	4.85
600	3.28	3.02	3.77	2.85	1.83	2.99	1.87	9.05	8.03	5.24
800	3.82	3.56	3.96	3.07	2.19	2.98	1.68	9.33	8.27	4.99
978	4.35	4.09	4.37	3.30	2.28	2.91	1.54	8.79	8.31	5.78
1000	4.42	4.15	4.42	3.33	2.29	2.9	1.52	8.72	8.32	5.88
1500	5.92	5.62	5.88	4.52	2.95	2.75	1.23	6.98	7.16	5.71
2000	7.64	7.32	7.57	6.09	3.93	2.51	0.84	4.7	4.88	4.88
2500	9.53	9.19	9.44	7.9	5.59	2.29	0.48	2.68	2.77	3.77
3000	11.5	11.13	11.38	9.83	7.53	2.11	0.3	1.67	1.71	3.05
3500	13.49	13.11	13.36	11.8	9.52	1.95	0.23	1.25	1.28	2.6
4000	15.51	15.1	15.35	13.8	11.53	1.79	0.15	0.84	0.85	2.29
4500	17.52	17.11	17.35	15.8	13.54	1.65	0.1	0.52	0.53	2.09
5000	19.54	19.12	19.36	17.81	15.56	1.54	0.09	0.47	0.47	1.93
5500	21.57	21.14	21.38	19.83	17.59	1.45	0.11	0.59	0.59	1.99

* Fish can pass either through Flume 1 and 2 or over the weir, thus criteria do not need to be met both in the flume and over the weir in order for fish to pass

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-19. Adult *O. mykiss* passage performance at CCTRR

Model	Depth (ft)					Velocity (ft/s)				
Flow (cfs)	Riprap 2	Riprap 1	Flume 2*	Flume 1*	Weir*	Riprap 2	Riprap 1	Flume 2*	Flume 1*	Weir*
2	0.76	0.74	1.38	0.19	0.03	1.43	0.65	2.19	2.02	0
5	1.02	0.89	1.51	0.31	0.03	1.28	0.8	3.03	2.93	0
6	1.05	0.92	1.54	0.34	0.03	1.28	0.85	3.19	3.09	0
10	1.15	1.02	1.68	0.47	0.03	1.26	1.06	3.81	3.75	0
15	1.21	1.1	1.81	0.6	0.03	1.42	1.28	4.36	4.35	0
20	1.26	1.17	1.94	0.72	0.03	1.55	1.48	4.8	4.81	0
30	1.35	1.28	2.16	0.95	0.02	1.71	1.78	5.47	5.45	0
40	1.43	1.38	2.36	1.15	0.02	1.79	2.02	6	5.99	0
50	1.49	1.45	2.5	1.29	0.19	1.9	2.18	6.38	6.33	2.02
75	1.64	1.56	2.71	1.51	0.48	2.1	2.37	6.91	6.78	2.87
100	1.78	1.65	2.84	1.69	0.66	2.18	2.42	7.2	6.91	2.99
150	2	1.81	3.02	1.93	0.87	2.4	2.4	7.59	7.04	3.58
200	2.17	1.96	3.16	2.11	1.02	2.58	2.34	7.89	7.22	4.04
210	2.21	2.00	3.19	2.15	1.06	2.60	2.33	7.95	7.27	4.06
300	2.48	2.25	3.4	2.4	1.33	2.76	2.25	8.34	7.56	4.2
400	2.75	2.51	3.54	2.57	1.56	2.91	2.11	8.62	7.73	4.43
500	3.01	2.76	3.66	2.71	1.7	2.98	1.98	8.83	7.89	4.85
600	3.28	3.02	3.77	2.85	1.83	2.99	1.87	9.05	8.03	5.24
800	3.82	3.56	3.96	3.07	2.19	2.98	1.68	9.33	8.27	4.99
1000	4.42	4.15	4.42	3.33	2.29	2.9	1.52	8.72	8.32	5.88
1500	5.92	5.62	5.88	4.52	2.95	2.75	1.23	6.98	7.16	5.71
2000	7.64	7.32	7.57	6.09	3.93	2.51	0.84	4.7	4.88	4.88
2500	9.53	9.19	9.44	7.9	5.59	2.29	0.48	2.68	2.77	3.77
3000	11.5	11.13	11.38	9.83	7.53	2.11	0.3	1.67	1.71	3.05
3500	13.49	13.11	13.36	11.8	9.52	1.95	0.23	1.25	1.28	2.6
4000	15.51	15.1	15.35	13.8	11.53	1.79	0.15	0.84	0.85	2.29
4500	17.52	17.11	17.35	15.8	13.54	1.65	0.1	0.52	0.53	2.09
4540	17.68	17.27	17.51	15.96	13.70	1.64	0.10	0.52	0.53	2.08
5000	19.54	19.12	19.36	17.81	15.56	1.54	0.09	0.47	0.47	1.93
5500	21.57	21.14	21.38	19.83	17.59	1.45	0.11	0.59	0.59	1.99

* Fish can pass either through Flume 1 and 2 or over the weir, thus criteria do not need to be met both in the flume and over the weir in order for fish to pass

indicates that depth criteria are met at the section

indicates that velocity criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-20. Juvenile salmonid passage performance at CCTRR

Model	Depth (ft)					Velocity (ft/s)				
Flow (cfs)	Riprap 2	Riprap 1	Flume 2*	Flume 1*	Weir*	Riprap 2	Riprap 1	Flume 2*	Flume 1*	Weir*
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	0.76	0.74	1.38	0.19	0.03	1.43	0.65	2.19	2.02	0
5	1.02	0.89	1.51	0.31	0.03	1.28	0.8	3.03	2.93	0
6	1.05	0.92	1.54	0.34	0.03	1.28	0.85	3.19	3.09	0
10	1.15	1.02	1.68	0.47	0.03	1.26	1.06	3.81	3.75	0
11	1.16	1.04	1.71	0.50	0.03	1.29	1.10	3.92	3.87	0
15	1.21	1.1	1.81	0.6	0.03	1.42	1.28	4.36	4.35	0
20	1.26	1.17	1.94	0.72	0.03	1.55	1.48	4.8	4.81	0
30	1.35	1.28	2.16	0.95	0.02	1.71	1.78	5.47	5.45	0
40	1.43	1.38	2.36	1.15	0.02	1.79	2.02	6	5.99	0
50	1.49	1.45	2.5	1.29	0.19	1.9	2.18	6.38	6.33	2.02
75	1.64	1.56	2.71	1.51	0.48	2.1	2.37	6.91	6.78	2.87
100	1.78	1.65	2.84	1.69	0.66	2.18	2.42	7.2	6.91	2.99
150	2	1.81	3.02	1.93	0.87	2.4	2.4	7.59	7.04	3.58
200	2.17	1.96	3.16	2.11	1.02	2.58	2.34	7.89	7.22	4.04
300	2.48	2.25	3.4	2.4	1.33	2.76	2.25	8.34	7.56	4.2
400	2.75	2.51	3.54	2.57	1.56	2.91	2.11	8.62	7.73	4.43
500	3.01	2.76	3.66	2.71	1.7	2.98	1.98	8.83	7.89	4.85
600	3.28	3.02	3.77	2.85	1.83	2.99	1.87	9.05	8.03	5.24
800	3.82	3.56	3.96	3.07	2.19	2.98	1.68	9.33	8.27	4.99
847	3.96	3.70	4.07	3.13	2.21	2.96	1.64	9.19	8.28	5.20
1000	4.42	4.15	4.42	3.33	2.29	2.9	1.52	8.72	8.32	5.88
1500	5.92	5.62	5.88	4.52	2.95	2.75	1.23	6.98	7.16	5.71
2000	7.64	7.32	7.57	6.09	3.93	2.51	0.84	4.7	4.88	4.88
2500	9.53	9.19	9.44	7.9	5.59	2.29	0.48	2.68	2.77	3.77
3000	11.5	11.13	11.38	9.83	7.53	2.11	0.3	1.67	1.71	3.05
3500	13.49	13.11	13.36	11.8	9.52	1.95	0.23	1.25	1.28	2.6
4000	15.51	15.1	15.35	13.8	11.53	1.79	0.15	0.84	0.85	2.29
4500	17.52	17.11	17.35	15.8	13.54	1.65	0.1	0.52	0.53	2.09
5000	19.54	19.12	19.36	17.81	15.56	1.54	0.09	0.47	0.47	1.93
5500	21.57	21.14	21.38	19.83	17.59	1.45	0.11	0.59	0.59	1.99

* Fish can pass either through flume 1 and 2 or over the weir, thus criteria do not need to be met both in the flume and over the weir in order for fish to pass

indicates that depth criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the juvenile salmonids migration period

Table 5-21. Adult Chinook passage performance at Budiselich Flashboard Dam

Model	Depth (ft)				Velocity (ft/s)			
Flow (cfs)	Riprap 3	Riprap 2	Riprap 1	Dam	Riprap 3	Riprap 2	Riprap 1	Dam
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	0.27	0.41	0.09	0.13	2.05	5.43	1.47	0.89
10	0.35	0.55	0.13	0.18	2.74	5.97	1.65	1.16
15	0.43	0.68	0.16	0.21	3.07	5.82	1.9	1.4
20	0.49	0.78	0.19	0.24	3.36	5.91	1.98	1.61
30	0.6	1	0.23	0.28	3.83	5.41	2.28	1.96
40	0.57	1.24	0.25	0.32	5.51	4.6	2.62	2.21
50	0.6	1.37	0.32	0.34	6.31	4.61	2.46	2.6
60	0.65	1.47	0.4	0.38	6.75	4.77	2.23	2.78
70	0.7	1.55	0.49	0.44	7.07	4.94	2.05	2.76
80	0.75	1.63	0.57	0.51	7.37	5.08	1.94	2.67
100	1.95	1.86	0.71	0.63	2.55	4.58	1.91	2.63
150	2.88	2.13	0.94	0.85	2.26	4.51	2.08	2.86
200	3.46	2.26	1.12	1.02	2.29	4.89	2.29	3.16
250	4.06	2.39	1.27	1.16	1.89	5.12	2.48	3.44
300	4.38	2.52	1.41	1.29	1.85	5.27	2.65	3.71
400	4.75	2.75	1.63	1.49	2.04	5.38	3	4.27
500	5.09	2.9	1.82	1.65	2.19	5.72	3.32	4.8
570	5.31	3.12	2.00	1.81	2.25	5.50	3.30	4.91
978	6.58	4.39	3.03	2.76	2.57	4.21	3.17	5.53
1000	6.65	4.46	3.09	2.81	2.59	4.14	3.16	5.56
1500	8.14	5.95	4.52	4.33	2.73	3.68	3.12	4.59
2000	9.64	7.44	5.98	5.84	2.77	3.42	3.05	4.08
2500	11.15	8.96	7.49	7.37	2.75	3.2	2.93	3.63
3000	12.67	10.48	9	8.91	2.53	2.86	2.67	3.13
4000	15.7	13.49	12	11.92	2.11	2.27	2.19	2.4
5000	18.76	16.55	15.05	14.97	1.87	1.97	1.91	2.04
6000	21.83	19.63	18.12	18.05	1.72	1.78	1.75	1.83

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-22. Adult *O. mykiss* passage performance at Budiselich Flashboard Dam

Model	Depth (ft)				Velocity (ft/s)			
Flow (cfs)	Riprap 3	Riprap 2	Riprap 1	Dam	Riprap 3	Riprap 2	Riprap 1	Dam
5	0.27	0.41	0.09	0.13	2.05	5.43	1.47	0.89
6	0.29	0.44	0.10	0.14	2.19	5.54	1.51	0.94
10	0.35	0.55	0.13	0.18	2.74	5.97	1.65	1.16
15	0.43	0.68	0.16	0.21	3.07	5.82	1.9	1.4
20	0.49	0.78	0.19	0.24	3.36	5.91	1.98	1.61
30	0.6	1	0.23	0.28	3.83	5.41	2.28	1.96
40	0.57	1.24	0.25	0.32	5.51	4.6	2.62	2.21
50	0.6	1.37	0.32	0.34	6.31	4.61	2.46	2.6
60	0.65	1.47	0.4	0.38	6.75	4.77	2.23	2.78
70	0.7	1.55	0.49	0.44	7.07	4.94	2.05	2.76
80	0.75	1.63	0.57	0.51	7.37	5.08	1.94	2.67
100	1.95	1.86	0.71	0.63	2.55	4.58	1.91	2.63
150	2.88	2.13	0.94	0.85	2.26	4.51	2.08	2.86
200	3.46	2.26	1.12	1.02	2.29	4.89	2.29	3.16
250	4.06	2.39	1.27	1.16	1.89	5.12	2.48	3.44
300	4.38	2.52	1.41	1.29	1.85	5.27	2.65	3.71
400	4.75	2.75	1.63	1.49	2.04	5.38	3	4.27
500	5.09	2.9	1.82	1.65	2.19	5.72	3.32	4.8
570	5.31	3.12	2.00	1.81	2.25	5.50	3.30	4.91
1000	6.65	4.46	3.09	2.81	2.59	4.14	3.16	5.56
1500	8.14	5.95	4.52	4.33	2.73	3.68	3.12	4.59
2000	9.64	7.44	5.98	5.84	2.77	3.42	3.05	4.08
2500	11.15	8.96	7.49	7.37	2.75	3.2	2.93	3.63
3000	12.67	10.48	9	8.91	2.53	2.86	2.67	3.13
4000	15.7	13.49	12	11.92	2.11	2.27	2.19	2.4
4540	17.35	15.14	13.65	13.57	1.98	2.11	2.04	2.21
5000	18.76	16.55	15.05	14.97	1.87	1.97	1.91	2.04
6000	21.83	19.63	18.12	18.05	1.72	1.78	1.75	1.83

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-23. Juvenile salmonid passage performance at Budiselich Flashboard Dam

Model	Depth (ft)				Velocity (ft/s)			
Flow (cfs)	Riprap 3	Riprap 2	Riprap 1	Dam	Riprap 3	Riprap 2	Riprap 1	Dam
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	0.27	0.41	0.09	0.13	2.05	5.43	1.47	0.89
10	0.35	0.55	0.13	0.18	2.74	5.97	1.65	1.16
15	0.43	0.68	0.16	0.21	3.07	5.82	1.9	1.4
20	0.49	0.78	0.19	0.24	3.36	5.91	1.98	1.61
30	0.6	1	0.23	0.28	3.83	5.41	2.28	1.96
40	0.57	1.24	0.25	0.32	5.51	4.6	2.62	2.21
50	0.6	1.37	0.32	0.34	6.31	4.61	2.46	2.6
60	0.65	1.47	0.4	0.38	6.75	4.77	2.23	2.78
70	0.7	1.55	0.49	0.44	7.07	4.94	2.05	2.76
80	0.75	1.63	0.57	0.51	7.37	5.08	1.94	2.67
100	1.95	1.86	0.71	0.63	2.55	4.58	1.91	2.63
150	2.88	2.13	0.94	0.85	2.26	4.51	2.08	2.86
170	3.11	2.18	1.00	0.92	2.27	4.66	2.16	2.98
200	3.46	2.26	1.12	1.02	2.29	4.89	2.29	3.16
250	4.06	2.39	1.27	1.16	1.89	5.12	2.48	3.44
300	4.38	2.52	1.41	1.29	1.85	5.27	2.65	3.71
400	4.75	2.75	1.63	1.49	2.04	5.38	3	4.27
500	5.09	2.9	1.82	1.65	2.19	5.72	3.32	4.8
847	6.17	3.98	2.70	2.46	2.47	4.62	3.21	5.33
1000	6.65	4.46	3.09	2.81	2.59	4.14	3.16	5.56
1500	8.14	5.95	4.52	4.33	2.73	3.68	3.12	4.59
2000	9.64	7.44	5.98	5.84	2.77	3.42	3.05	4.08
2500	11.15	8.96	7.49	7.37	2.75	3.2	2.93	3.63
3000	12.67	10.48	9	8.91	2.53	2.86	2.67	3.13
4000	15.7	13.49	12	11.92	2.11	2.27	2.19	2.4
5000	18.76	16.55	15.05	14.97	1.87	1.97	1.91	2.04
6000	21.83	19.63	18.12	18.05	1.72	1.78	1.75	1.83

indicates that depth criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-24. Adult Chinook passage performance at Caprini Low Flow Road Crossing

Model Flow (cfs)	Depth (ft) Riprap	Depth (ft) Apron	Depth (ft) Culvert*	Depth (ft) Weir*	Velocity (ft/s) Riprap	Velocity (ft/s) Apron	Velocity (ft/s) Culvert*	Velocity (ft/s) Weir*
2	0.08	0.11	0.24		1.99	1.86	2.53	
3	0.10	0.14	0.28		2.25	2.02	2.79	
5	0.13	0.20	0.37		2.77	2.35	3.32	
10	0.21	0.31	0.53		3.48	2.81	4.01	
15	0.28	0.39	0.64		3.96	3.21	4.53	
20	0.33	0.46	0.73		4.39	3.53	4.98	
30	0.42	0.58	0.91		5.09	3.99	5.57	
40	0.51	0.68	1.05		5.59	4.41	6.03	
50	0.58	0.78	1.20		6.01	4.74	6.35	
75	0.76	1.00	1.50		6.79	5.42	7.08	
100	0.90	1.19	1.78		7.42	5.96	7.64	
150	1.15	1.53	2.30		8.42	6.85	8.59	
200	1.36	1.84	2.50	0.33	9.20	7.54	9.51	1.55
300	1.71	2.39	2.58	0.79	10.41	8.62	9.99	2.58
400	2.01	2.87	2.37	1.11	11.36	9.49	11.33	3.10
500	2.25	3.32	3	1.43	12.18	10.22	8.90	3.52
600	2.45	3.74	3	1.74	12.90	10.85	7.59	3.87
730	3.28	4.07	3	1.96	9.99	8.03	8.55	4.11
800	3.72	4.25	3	2.08	8.42	6.51	9.07	4.25
978	4.11	4.68	3	2.40	8.48	6.71	8.83	4.58
1000	4.16	4.73	3	2.44	8.49	6.74	8.80	4.63
1500	6.69	6.37	3	3.25	5.50	5.78	7.17	5.37
2000	9.10	8.90	3	4.55	4.40	4.11	2.60	5.14
2500	11.47	11.20	3	6.75	3.71	3.49	1.85	4.06
3000	13.82	13.53	3	9.01	3.29	3.10	1.82	3.46
3500	16.17	15.86	3	11.31	3.01	2.84	1.89	3.07
4000	18.51	18.20	3	13.63	2.79	2.63	1.10	2.81
4500	20.86	20.53	3	15.95	2.61	2.47	1.76	2.59
5000	23.20	22.87	3	18.28	2.47	2.34	1.67	2.41
5500	25.54	25.21	3	20.61	2.34	2.23	1.65	2.28

* Fish can pass either through the culverts or over the weir, thus criteria do not need to be met both in the culverts and over the weir in order for fish to pass

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-25. Adult *O. mykiss* passage performance at Caprini Low Flow Road Crossing

Model Flow (cfs)	Depth (ft) Riprap	Depth (ft) Apron	Depth (ft) Culvert*	Depth (ft) Weir*	Velocity (ft/s) Riprap	Velocity (ft/s) Apron	Velocity (ft/s) Culvert*	Velocity (ft/s) Weir*
2	0.08	0.11	0.24		1.99	1.86	2.53	
5	0.13	0.20	0.37		2.77	2.35	3.32	
6	0.15	0.22	0.40		2.91	2.44	3.46	
10	0.21	0.31	0.53		3.48	2.81	4.01	
15	0.28	0.39	0.64		3.96	3.21	4.53	
20	0.33	0.46	0.73		4.39	3.53	4.98	
30	0.42	0.58	0.91		5.09	3.99	5.57	
40	0.51	0.68	1.05		5.59	4.41	6.03	
50	0.58	0.78	1.20		6.01	4.74	6.35	
75	0.76	1.00	1.50		6.79	5.42	7.08	
100	0.90	1.19	1.78		7.42	5.96	7.64	
150	1.15	1.53	2.30		8.42	6.85	8.59	
200	1.36	1.84	2.50	0.33	9.20	7.54	9.51	1.55
300	1.71	2.39	2.58	0.79	10.41	8.62	9.99	2.58
400	2.01	2.87	2.37	1.11	11.36	9.49	11.33	3.10
500	2.25	3.32	3	1.43	12.18	10.22	8.90	3.52
600	2.45	3.74	3	1.74	12.90	10.85	7.59	3.87
730	3.28	4.07	3	1.96	9.99	8.03	8.55	4.11
800	3.72	4.25	3	2.08	8.42	6.51	9.07	4.25
1000	4.16	4.73	3	2.44	8.49	6.74	8.80	4.63
1500	6.69	6.37	3	3.25	5.50	5.78	7.17	5.37
2000	9.10	8.90	3	4.55	4.40	4.11	2.60	5.14
2500	11.47	11.20	3	6.75	3.71	3.49	1.85	4.06
3000	13.82	13.53	3	9.01	3.29	3.10	1.82	3.46
3500	16.17	15.86	3	11.31	3.01	2.84	1.89	3.07
4000	18.51	18.20	3	13.63	2.79	2.63	1.10	2.81
4500	20.86	20.53	3	15.95	2.61	2.47	1.76	2.59
4540	21.05	20.72	3	16.14	2.60	2.46	1.75	2.58
5000	23.20	22.87	3.00	18.28	2.47	2.34	1.67	2.41
5500	25.54	25.21	3.00	20.61	2.34	2.23	1.65	2.28

* Fish can pass either through the culverts or over the weir, thus criteria do not need to be met both in the culverts and over the weir in order for fish to pass

indicates that depth criteria are met at the section

indicates that velocity criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-26. Juvenile salmonid passage performance at Caprini Low Flow Road Crossing

Model	Depth (ft)				Velocity (ft/s)			
Flow (cfs)	Riprap	Apron	Culvert*	Weir*	Riprap	Apron	Culvert*	Weir*
1	N/A	N/A	N/A		N/A	N/A	N/A	
2	0.08	0.11	0.24		1.99	1.86	2.53	
5	0.13	0.20	0.37		2.77	2.35	3.32	
10	0.21	0.31	0.53		3.48	2.81	4.01	
15	0.28	0.39	0.64		3.96	3.21	4.53	
20	0.33	0.46	0.73		4.39	3.53	4.98	
30	0.42	0.58	0.91		5.09	3.99	5.57	
40	0.51	0.68	1.05		5.59	4.41	6.03	
50	0.58	0.78	1.20		6.01	4.74	6.35	
75	0.76	1.00	1.50		6.79	5.42	7.08	
100	0.90	1.19	1.78		7.42	5.96	7.64	
120	1.00	1.33	1.99		7.82	6.32	8.02	
150	1.15	1.53	2.30		8.42	6.85	8.59	
200	1.36	1.84	2.50	0.33	9.20	7.54	9.51	1.55
300	1.71	2.39	2.58	0.79	10.41	8.62	9.99	2.58
400	2.01	2.87	2.37	1.11	11.36	9.49	11.33	3.10
500	2.25	3.32	3	1.43	12.18	10.22	8.90	3.52
600	2.45	3.74	3	1.74	12.90	10.85	7.59	3.87
800	3.72	4.25	3	2.08	8.42	6.51	9.07	4.25
847	3.82	4.36	3	2.16	8.44	6.56	9.01	4.34
1000	4.16	4.73	3	2.44	8.49	6.74	8.80	4.63
1500	6.69	6.37	3	3.25	5.50	5.78	7.17	5.37
2000	9.10	8.90	3	4.55	4.40	4.11	2.60	5.14
2500	11.47	11.20	3	6.75	3.71	3.49	1.85	4.06
3000	13.82	13.53	3	9.01	3.29	3.10	1.82	3.46
3500	16.17	15.86	3	11.31	3.01	2.84	1.89	3.07
4000	18.51	18.20	3	13.63	2.79	2.63	1.10	2.81
4500	20.86	20.53	3	15.95	2.61	2.47	1.76	2.59
5000	23.20	22.87	3	18.28	2.47	2.34	1.67	2.41
5500	25.54	25.21	3	20.61	2.34	2.23	1.65	2.28

* Fish can pass either through the culverts or over the weir, thus criteria do not need to be met both in the culverts and over the weir in order for fish to pass

indicates that depth criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-27. Adult Chinook passage performance at Hogan Low Flow Road Crossing

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	Riprap 2	Riprap 1	Culvert 1*	Culvert 2*	Culvert 3*	Crossing*	Riprap 2	Riprap 1	Culvert 1*	Culvert 2*	Culvert 3*	Crossing*
2	5.57	1.54	0.03	0.46	0.01		0.02	0.1	0.75	3.21	0.45	
3	5.60	1.57	0.08	0.46	0.06		0.03	0.14	1.17	4.41	0.94	
5	5.67	1.64	0.19	0.47	0.17		0.06	0.23	2.01	6.82	1.91	
10	5.81	1.78	0.40	0.6	0.37		0.11	0.42	2.99	7.65	2.86	
15	5.91	1.88	0.55	0.69	0.52		0.16	0.58	3.54	8.19	3.41	
20	6.01	1.98	0.67	0.77	0.65		0.2	0.74	3.93	8.59	3.82	
30	6.17	2.14	0.89	0.91	0.86		0.29	1.01	4.58	9.18	4.41	
37	6.25	2.22	1.00	0.99	0.99		0.35	1.19	4.92	9.50	4.75	
40	6.29	2.26	1.05	1.03	1.04		0.38	1.27	5.07	9.64	4.9	
50	6.4	2.36	1.2	1.13	1.2		0.46	1.51	5.48	10	5.33	
69	6.58	2.54	1.43	1.31	1.48		0.60	1.91	6.15	10.57	6.00	
75	6.64	2.6	1.5	1.37	1.57		0.65	2.03	6.36	10.75	6.21	
100	6.85	2.8	1.73	2.5	1.9		0.82	2.49	7.12	7.48	7.02	
150	7.21	3.15	1.98	2.5	2.32	0.41	1.13	3.28	8.15	10.1	8.11	1.57
200	7.53	3.45	2.08	2.5	2.48	0.78	1.4	3.95	8.65	10.23	8.59	2.10
245	7.81	3.72	2.12	2.50	2.56	1.00	1.60	4.41	8.93	10.05	8.86	2.40
300	8.15	4.05	2.17	2.5	2.66	1.27	1.85	4.98	9.28	9.83	9.18	2.77
400	8.68	4.56	2.23	2.5	2.78	1.66	2.22	5.84	9.77	9.41	9.64	3.24
500	9.19	5.23	2.5	2.5	2.87	2.01	2.53	4.84	8.92	8.89	10.03	3.61
600	9.68	5.77	2.5	2.5	3.5	2.34	2.79	4.84	8.34	8.35	8.87	3.93
800	10.61	6.81	2.5	2.5	3.5	2.96	3.15	4.56	7.16	7.23	7.81	4.46
978	11.42	7.67	2.50	2.50	3.50	3.46	3.35	4.28	6.09	6.13	6.59	4.83
1000	12	7.78	2.50	2.5	3.5	3.52	3.38	4.25	5.96	5.99	6.44	4.88
1500	13.94	10.3	2.5	2.5	3.5	5.41	3.56	3.71	2.74	2.93	3.11	4.76
2000	16.44	12.88	2.5	2.5	3.5	7.92	3.48	3.34	2.54	2.71	2.9	4.11
2500	19	15.42	2.50	2.5	3.5	10.42	3.31	3.10	2.3	2.44	2.62	3.67
3000	21.59	17.98	2.5	2.5	3.5	12.93	3.12	2.9	2	1.77	1.69	3.32
3500	24.21	20.58	2.5	2.5	3.5	15.51	2.85	2.73	1.89	1.99	2.15	3.04
4000	26.81	23.14	2.5	2.5	3.5	18.06	2.58	2.58	1.88	2.01	2.16	2.85
4500	29.42	25.73	2.5	2.5	3.5	20.64	2.38	2.43	1.84	1.94	2.11	2.59
5000	32.04	28.34	2.5	2.5	3.5	23.23	2.21	2.29	1.84	1.92	2.07	2.43
5500	34.66	30.95	2.5	2.5	3.5	25.84	2.09	2.18	2.14	1.9	1.85	2.32

* Fish can pass either through the culverts or over the weir, thus criteria do not need to be met both in the culverts and over the weir in order for fish to pass

indicates that depth criteria are met at the section

indicates that velocity criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-28. Adult *O. mykiss* passage performance at Hogan Low Flow Road Crossing

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	Riprap 2	Riprap 1	Culvert 1*	Culvert 2*	Culvert 3*	Crossing*	Riprap 2	Riprap 1	Culvert 1*	Culvert 2*	Culvert 3*	Crossing*
2	5.57	1.54	0.03	0.46	0.01		0.02	0.1	0.75	3.21	0.45	
5	5.67	1.64	0.19	0.47	0.17		0.06	0.23	2.01	6.82	1.91	
6	5.70	1.67	0.23	0.50	0.21		0.07	0.27	2.21	6.99	2.10	
10	5.81	1.78	0.40	0.6	0.37		0.11	0.42	2.99	7.65	2.86	
15	5.91	1.88	0.55	0.69	0.52		0.16	0.58	3.54	8.19	3.41	
20	6.01	1.98	0.67	0.77	0.65		0.2	0.74	3.93	8.59	3.82	
30	6.17	2.14	0.89	0.91	0.86		0.29	1.01	4.58	9.18	4.41	
37	6.25	2.22	1.00	0.99	0.99		0.35	1.19	4.92	9.50	4.75	
40	6.29	2.26	1.05	1.03	1.04		0.38	1.27	5.07	9.64	4.9	
50	6.4	2.36	1.2	1.13	1.2		0.46	1.51	5.48	10	5.33	
69	6.58	2.54	1.43	1.31	1.48		0.60	1.91	6.15	10.57	6.00	
75	6.64	2.6	1.5	1.37	1.57		0.65	2.03	6.36	10.75	6.21	
100	6.85	2.8	1.73	2.5	1.9		0.82	2.49	7.12	7.48	7.02	
150	7.21	3.15	1.98	2.5	2.32	0.41	1.13	3.28	8.15	10.1	8.11	1.57
200	7.53	3.45	2.08	2.5	2.48	0.78	1.4	3.95	8.65	10.23	8.59	2.10
245	7.81	3.72	2.12	2.50	2.56	1.00	1.60	4.41	8.93	10.05	8.86	2.40
300	8.15	4.05	2.17	2.5	2.66	1.27	1.85	4.98	9.28	9.83	9.18	2.77
400	8.68	4.56	2.23	2.5	2.78	1.66	2.22	5.84	9.77	9.41	9.64	3.24
500	9.19	5.23	2.5	2.5	2.87	2.01	2.53	4.84	8.92	8.89	10.03	3.61
600	9.68	5.77	2.5	2.5	3.5	2.34	2.79	4.84	8.34	8.35	8.87	3.93
800	10.61	6.81	2.5	2.5	3.5	2.96	3.15	4.56	7.16	7.23	7.81	4.46
1000	12	7.78	2.50	2.5	3.5	3.52	3.38	4.25	5.96	5.99	6.44	4.88
1500	13.94	10.3	2.5	2.5	3.5	5.41	3.56	3.71	2.74	2.93	3.11	4.76
2000	16.44	12.88	2.5	2.5	3.5	7.92	3.48	3.34	2.54	2.71	2.9	4.11
2500	19	15.42	2.50	2.5	3.5	10.42	3.31	3.10	2.3	2.44	2.62	3.67
3000	21.59	17.98	2.5	2.5	3.5	12.93	3.12	2.9	2	1.77	1.69	3.32
3500	24.21	20.58	2.5	2.5	3.5	15.51	2.85	2.73	1.89	1.99	2.15	3.04
4000	26.81	23.14	2.5	2.5	3.5	18.06	2.58	2.58	1.88	2.01	2.16	2.85
4500	29.42	25.73	2.5	2.5	3.5	20.64	2.38	2.43	1.84	1.94	2.11	2.59
4540	29.63	25.94	2.50	2.50	3.50	20.85	2.37	2.42	1.84	1.94	2.11	2.58
5000	32.04	28.34	2.5	2.5	3.5	23.23	2.21	2.29	1.84	1.92	2.07	2.43
5500	34.66	30.95	2.5	2.5	3.5	25.84	2.09	2.18	2.14	1.9	1.85	2.32

* Fish can pass either through the culverts or over the weir, thus criteria do not need to be met both in the culverts and over the weir in order for fish to pass

indicates that depth criteria are met at the section

indicates that velocity criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-29. Juvenile salmonid passage performance at Hogan Low Flow Road Crossing

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	Riprap 2	Riprap 1	Culvert 1*	Culvert 2*	Culvert 3*	Crossing*	Riprap 2	Riprap 1	Culvert 1*	Culvert 2*	Culvert 3*	Crossing*
1	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A	
2	5.57	1.54	0.03	0.46	0.01		0.02	0.1	0.75	3.21	0.45	
5	5.67	1.64	0.19	0.47	0.17		0.06	0.23	2.01	6.82	1.91	
6	5.70	1.67	0.23	0.50	0.21		0.07	0.27	2.21	6.99	2.10	
10	5.81	1.78	0.40	0.6	0.37		0.11	0.42	2.99	7.65	2.86	
15	5.91	1.88	0.55	0.69	0.52		0.16	0.58	3.54	8.19	3.41	
20	6.01	1.98	0.67	0.77	0.65		0.2	0.74	3.93	8.59	3.82	
30	6.17	2.14	0.89	0.91	0.86		0.29	1.01	4.58	9.18	4.41	
40	6.29	2.26	1.05	1.03	1.04		0.38	1.27	5.07	9.64	4.9	
50	6.4	2.36	1.2	1.13	1.2		0.46	1.51	5.48	10	5.33	
75	6.64	2.6	1.5	1.37	1.57		0.65	2.03	6.36	10.75	6.21	
100	6.85	2.8	1.73	2.5	1.9		0.82	2.49	7.12	7.48	7.02	
150	7.21	3.15	1.98	2.5	2.32	0.41	1.13	3.28	8.15	10.1	8.11	1.57
200	7.53	3.45	2.08	2.5	2.48	0.78	1.4	3.95	8.65	10.23	8.59	2.10
300	8.15	4.05	2.17	2.5	2.66	1.27	1.85	4.98	9.28	9.83	9.18	2.77
400	8.68	4.56	2.23	2.5	2.78	1.66	2.22	5.84	9.77	9.41	9.64	3.24
500	9.19	5.23	2.5	2.5	2.87	2.01	2.53	4.84	8.92	8.89	10.03	3.61
600	9.68	5.77	2.5	2.5	3.5	2.34	2.79	4.84	8.34	8.35	8.87	3.93
800	10.61	6.81	2.5	2.5	3.5	2.96	3.15	4.56	7.16	7.23	7.81	4.46
847	10.82	7.04	2.50	2.50	3.50	3.09	3.20	4.49	6.88	6.94	7.49	4.56
1000	12	7.78	2.50	2.5	3.5	3.52	3.38	4.25	5.96	5.99	6.44	4.88
1500	13.94	10.3	2.5	2.5	3.5	5.41	3.56	3.71	2.74	2.93	3.11	4.76
2000	16.44	12.88	2.5	2.5	3.5	7.92	3.48	3.34	2.54	2.71	2.9	4.11
2500	19	15.42	2.50	2.5	3.5	10.42	3.31	3.10	2.3	2.44	2.62	3.67
3000	21.59	17.98	2.5	2.5	3.5	12.93	3.12	2.9	2	1.77	1.69	3.32
3500	24.21	20.58	2.5	2.5	3.5	15.51	2.85	2.73	1.89	1.99	2.15	3.04
4000	26.81	23.14	2.5	2.5	3.5	18.06	2.58	2.58	1.88	2.01	2.16	2.85
4500	29.42	25.73	2.5	2.5	3.5	20.64	2.38	2.43	1.84	1.94	2.11	2.59
5000	32.04	28.34	2.5	2.5	3.5	23.23	2.21	2.29	1.84	1.92	2.07	2.43
5500	34.66	30.95	2.5	2.5	3.5	25.84	2.09	2.18	2.14	1.9	1.85	2.32

* Fish can pass either through the culverts or over the weir, thus criteria do not need to be met both in the culverts and over the weir in order for fish to pass

indicates that depth criteria are met at the section

indicates that velocity criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-30. Adult Chinook passage performance at Hosie Low Flow Road Crossing

Model	Depth (ft/s)			Velocity (ft/s)		
Flow (cfs)	Riprap 3	Riprap 2	Crossing	Riprap 3	Riprap 2	Crossing
2	0.25	0.12	0.09	2.5	2.04	2.27
5	0.36	0.23	0.13	3.06	2.65	2.93
10	0.47	0.4	0.17	3.56	2.81	3.44
15	0.55	0.47	0.21	3.91	3.22	3.68
20	0.6	0.54	0.24	4.18	3.53	3.84
25	0.65	0.6	0.27	4.46	3.83	3.83
30	0.69	0.71	0.28	4.64	3.59	4.02
35	0.73	0.75	0.3	4.84	3.79	4.14
40	0.77	0.79	0.32	5	3.98	4.26
50	0.82	0.87	0.35	5.34	4.24	4.45
60	0.89	1	0.38	5.49	3.99	4.59
70	0.94	1.06	0.41	5.65	4.11	4.73
80	0.99	1.11	0.44	5.8	4.27	4.86
90	1.03	1.17	0.47	5.94	4.37	4.97
100	1.07	1.23	0.5	6.05	4.37	5.11
120	1.15	1.32	0.55	6.25	4.46	5.24
150	1.26	1.44	0.63	6.46	4.69	5.36
200	1.41	1.6	0.76	6.79	5.04	5.57
250	1.54	1.74	0.87	7.07	5.3	5.79
300	1.66	1.87	0.98	7.29	5.53	5.95
350	1.76	1.98	1.08	7.53	5.74	6.06
400	1.88	2.09	1.19	7.65	5.93	6.16
460	2.01	2.21	1.30	7.78	6.12	6.28
500	2.1	2.29	1.37	7.87	6.24	6.36
600	2.74	2.45	1.54	6.01	6.59	6.57
700	3.04	2.61	1.73	5.92	6.88	6.59
800	3.39	2.88	1.87	5.68	6.62	6.83
900	3.71	3.19	1.99	5.56	6.3	7.08
1000	4.04	3.51	2.17	5.42	6.01	7.05
1500	5.97	5.44	3.89	4.49	4.6	4.97
1590	6.37	5.84	4.28	4.34	4.42	4.75
2000	8.2	7.66	6.04	3.64	3.62	3.74
2500	10.57	10.01	8.36	3.01	3.01	3.05
3000	12.97	12.4	10.75	2.59	2.6	2.62
4000	17.81	17.24	15.58	2.09	2.11	2.12
5000	22.74	22.18	20.51	1.81	1.83	1.83
6000	27.71	27.14	25.48	1.63	1.66	1.66

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-31. Adult *O. mykiss* passage performance at Hosie Low Flow Road Crossing

Model Flow (cfs)	Depth (ft/s) Riprap 3	Depth (ft/s) Riprap 2	Depth (ft/s) Crossing	Velocity (ft/s) Riprap 3	Velocity (ft/s) Riprap 2	Velocity (ft/s) Crossing
2	0.25	0.12	0.09	2.5	2.04	2.27
5	0.36	0.23	0.13	3.06	2.65	2.93
10	0.47	0.4	0.17	3.56	2.81	3.44
15	0.55	0.47	0.21	3.91	3.22	3.68
19	0.59	0.53	0.23	4.13	3.47	3.81
20	0.6	0.54	0.24	4.18	3.53	3.84
25	0.65	0.6	0.27	4.46	3.83	3.83
30	0.69	0.71	0.28	4.64	3.59	4.02
35	0.73	0.75	0.3	4.84	3.79	4.14
40	0.77	0.79	0.32	5	3.98	4.26
50	0.82	0.87	0.35	5.34	4.24	4.45
60	0.89	1	0.38	5.49	3.99	4.59
70	0.94	1.06	0.41	5.65	4.11	4.73
80	0.99	1.11	0.44	5.8	4.27	4.86
90	1.03	1.17	0.47	5.94	4.37	4.97
100	1.07	1.23	0.5	6.05	4.37	5.11
120	1.15	1.32	0.55	6.25	4.46	5.24
150	1.26	1.44	0.63	6.46	4.69	5.36
200	1.41	1.6	0.76	6.79	5.04	5.57
250	1.54	1.74	0.87	7.07	5.3	5.79
300	1.66	1.87	0.98	7.29	5.53	5.95
350	1.76	1.98	1.08	7.53	5.74	6.06
400	1.88	2.09	1.19	7.65	5.93	6.16
460	2.01	2.21	1.30	7.78	6.12	6.28
500	2.1	2.29	1.37	7.87	6.24	6.36
600	2.74	2.45	1.54	6.01	6.59	6.57
700	3.04	2.61	1.73	5.92	6.88	6.59
800	3.39	2.88	1.87	5.68	6.62	6.83
900	3.71	3.19	1.99	5.56	6.3	7.08
1000	4.04	3.51	2.17	5.42	6.01	7.05
1500	5.97	5.44	3.89	4.49	4.6	4.97
2000	8.2	7.66	6.04	3.64	3.62	3.74
2500	10.57	10.01	8.36	3.01	3.01	3.05
3000	12.97	12.4	10.75	2.59	2.6	2.62
4000	17.81	17.24	15.58	2.09	2.11	2.12
5000	22.74	22.18	20.51	1.81	1.83	1.83
5460	25.03	24.46	22.80	1.73	1.75	1.75
6000	27.71	27.14	25.48	1.63	1.66	1.66

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-32. Juvenile salmonid passage performance at Hosie Low Flow Road Crossing

Model Flow (cfs)	Depth (ft/s) Riprap 3	Depth (ft/s) Riprap 2	Depth (ft/s) Crossing	Velocity (ft/s) Riprap 3	Velocity (ft/s) Riprap 2	Velocity (ft/s) Crossing
1	N/A	N/A	N/A	N/A	N/A	N/A
2	0.25	0.12	0.09	2.5	2.04	2.27
5	0.36	0.23	0.13	3.06	2.65	2.93
10	0.47	0.4	0.17	3.56	2.81	3.44
15	0.55	0.47	0.21	3.91	3.22	3.68
20	0.6	0.54	0.24	4.18	3.53	3.84
25	0.65	0.6	0.27	4.46	3.83	3.83
30	0.69	0.71	0.28	4.64	3.59	4.02
35	0.73	0.75	0.3	4.84	3.79	4.14
40	0.77	0.79	0.32	5	3.98	4.26
50	0.82	0.87	0.35	5.34	4.24	4.45
60	0.89	1	0.38	5.49	3.99	4.59
70	0.94	1.06	0.41	5.65	4.11	4.73
80	0.99	1.11	0.44	5.8	4.27	4.86
90	1.03	1.17	0.47	5.94	4.37	4.97
100	1.07	1.23	0.5	6.05	4.37	5.11
120	1.15	1.32	0.55	6.25	4.46	5.24
150	1.26	1.44	0.63	6.46	4.69	5.36
200	1.41	1.6	0.76	6.79	5.04	5.57
250	1.54	1.74	0.87	7.07	5.3	5.79
300	1.66	1.87	0.98	7.29	5.53	5.95
350	1.76	1.98	1.08	7.53	5.74	6.06
400	1.88	2.09	1.19	7.65	5.93	6.16
500	2.1	2.29	1.37	7.87	6.24	6.36
600	2.74	2.45	1.54	6.01	6.59	6.57
700	3.04	2.61	1.73	5.92	6.88	6.59
800	3.39	2.88	1.87	5.68	6.62	6.83
900	3.71	3.19	1.99	5.56	6.3	7.08
1000	4.04	3.51	2.17	5.42	6.01	7.05
1248	5.00	4.47	3.02	4.96	5.31	6.02
1500	5.97	5.44	3.89	4.49	4.6	4.97
2000	8.2	7.66	6.04	3.64	3.62	3.74
2500	10.57	10.01	8.36	3.01	3.01	3.05
3000	12.97	12.4	10.75	2.59	2.6	2.62
4000	17.81	17.24	15.58	2.09	2.11	2.12
5000	22.74	22.18	20.51	1.81	1.83	1.83
6000	27.71	27.14	25.48	1.63	1.66	1.66

indicates that depth criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-33. Adult Chinook passage performance at Watkins Low Flow Road Crossing

Model	Depth (ft)			Velocity (ft/s)		
Flow (cfs)	Riprap 2	Riprap 1	Crossing	Riprap 2	Riprap 1	Crossing
2	0.36	0.19	0.07	2.13	3.71	1.04
5	0.51	0.27	0.1	2.66	4.32	1.4
10	0.67	0.37	0.13	3.17	4.78	1.77
15	0.78	0.44	0.16	3.53	5.12	1.99
20	0.87	0.5	0.19	3.84	5.34	2.16
30	1.03	0.62	0.23	4.12	5.58	2.44
40	1.16	0.72	0.27	4.36	5.73	2.64
50	1.27	0.82	0.31	4.57	5.79	2.83
75	1.41	1.06	0.39	5.56	5.71	3.17
100	1.69	1.24	0.46	4.75	5.65	3.46
150	1.88	1.56	0.58	5.51	5.32	3.93
200	2.1	1.71	0.69	5.69	5.5	4.26
300	2.88	1.94	0.87	4.25	5.87	4.86
380	3.27	2.30	1.00	4.01	4.96	5.24
400	3.37	2.39	1.03	3.95	4.73	5.34
500	3.68	2.66	1.18	4.08	4.71	5.69
600	3.95	2.9	1.35	4.23	4.73	5.8
800	4.58	3.46	1.88	4.19	4.48	5.24
1000	5.33	4.16	2.56	3.92	4.07	4.56
1500	7.42	6.21	4.6	3.19	3.22	3.4
1590	7.78	6.57	4.96	3.13	3.16	3.32
2000	9.41	8.2	6.58	2.86	2.86	2.97
2500	11.47	10.25	8.63	2.63	2.62	2.68
3000	13.56	12.34	10.72	2.43	2.41	2.45
3500	15.66	14.44	12.82	2.27	2.23	2.26
4000	17.76	16.54	14.92	2.14	2.1	2.12
4500	19.85	18.63	17.01	2.04	2	2.01
5000	21.95	20.72	19.1	1.95	1.91	1.92
5500	24.04	22.82	21.2	1.88	1.84	1.85

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-34. Adult *O. mykiss* passage performance at Watkins Low Flow Road Crossing

Model	Depth (ft)			Velocity (ft/s)		
Flow (cfs)	Riprap 2	Riprap 1	Crossing	Riprap 2	Riprap 1	Crossing
2	0.36	0.19	0.07	2.13	3.71	1.04
5	0.51	0.27	0.1	2.66	4.32	1.4
10	0.67	0.37	0.13	3.17	4.78	1.77
15	0.78	0.44	0.16	3.53	5.12	1.99
19	0.85	0.49	0.18	3.78	5.30	2.13
20	0.87	0.5	0.19	3.84	5.34	2.16
30	1.03	0.62	0.23	4.12	5.58	2.44
40	1.16	0.72	0.27	4.36	5.73	2.64
50	1.27	0.82	0.31	4.57	5.79	2.83
75	1.41	1.06	0.39	5.56	5.71	3.17
100	1.69	1.24	0.46	4.75	5.65	3.46
150	1.88	1.56	0.58	5.51	5.32	3.93
200	2.1	1.71	0.69	5.69	5.5	4.26
300	2.88	1.94	0.87	4.25	5.87	4.86
380	3.27	2.30	1.00	4.01	4.96	5.24
400	3.37	2.39	1.03	3.95	4.73	5.34
500	3.68	2.66	1.18	4.08	4.71	5.69
600	3.95	2.9	1.35	4.23	4.73	5.8
800	4.58	3.46	1.88	4.19	4.48	5.24
1000	5.33	4.16	2.56	3.92	4.07	4.56
1500	7.42	6.21	4.6	3.19	3.22	3.4
2000	9.41	8.2	6.58	2.86	2.86	2.97
2500	11.47	10.25	8.63	2.63	2.62	2.68
3000	13.56	12.34	10.72	2.43	2.41	2.45
3500	15.66	14.44	12.82	2.27	2.23	2.26
4000	17.76	16.54	14.92	2.14	2.1	2.12
4500	19.85	18.63	17.01	2.04	2	2.01
5000	21.95	20.72	19.1	1.95	1.91	1.92
5460	23.87	22.65	21.03	1.89	1.85	1.86
5500	24.04	22.82	21.2	1.88	1.84	1.85

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-35. Juvenile salmonid passage performance at Watkins Low Flow Road Crossing

Model	Depth (ft)			Velocity (ft/s)		
Flow (cfs)	Riprap 2	Riprap 1	Crossing	Riprap 2	Riprap 1	Crossing
1	N/A	N/A	N/A	N/A	N/A	N/A
2	0.36	0.19	0.07	2.13	3.71	1.04
5	0.51	0.27	0.1	2.66	4.32	1.4
10	0.67	0.37	0.13	3.17	4.78	1.77
15	0.78	0.44	0.16	3.53	5.12	1.99
20	0.87	0.5	0.19	3.84	5.34	2.16
30	1.03	0.62	0.23	4.12	5.58	2.44
40	1.16	0.72	0.27	4.36	5.73	2.64
50	1.27	0.82	0.31	4.57	5.79	2.83
75	1.41	1.06	0.39	5.56	5.71	3.17
100	1.69	1.24	0.46	4.75	5.65	3.46
120	1.77	1.37	0.50	5.05	5.52	3.65
150	1.88	1.56	0.58	5.51	5.32	3.93
200	2.1	1.71	0.69	5.69	5.5	4.26
300	2.88	1.94	0.87	4.25	5.87	4.86
400	3.37	2.39	1.03	3.95	4.73	5.34
500	3.68	2.66	1.18	4.08	4.71	5.69
600	3.95	2.9	1.35	4.23	4.73	5.8
800	4.58	3.46	1.88	4.19	4.48	5.24
1000	5.33	4.16	2.56	3.92	4.07	4.56
1248	6.37	5.18	3.57	3.56	3.65	3.98
1500	7.42	6.21	4.6	3.19	3.22	3.4
2000	9.41	8.2	6.58	2.86	2.86	2.97
2500	11.47	10.25	8.63	2.63	2.62	2.68
3000	13.56	12.34	10.72	2.43	2.41	2.45
3500	15.66	14.44	12.82	2.27	2.23	2.26
4000	17.76	16.54	14.92	2.14	2.1	2.12
4500	19.85	18.63	17.01	2.04	2	2.01
5000	21.95	20.72	19.1	1.95	1.91	1.92
5500	24.04	22.82	21.2	1.88	1.84	1.85

indicates that depth criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-36. Adult Chinook passage performance at Murphy Flashboard Dam

Model	Depth (ft)				Velocity (ft/s)			
Flow (cfs)	channel 2	dam 2	dam1	channel 1	channel 2	dam 2	dam1	channel 1
1	1.13	1.09	0.16	0.44	0.06	0.07	1.27	1.09
3	1.22	1.18	0.24	0.56	0.15	0.18	2.24	1.68
5	1.31	1.26	0.31	0.67	0.24	0.28	3.2	2.26
10	1.49	1.44	0.59	1.05	0.39	0.47	2.52	1.14
20	1.84	1.8	0.85	1.27	0.59	0.71	2.21	1.46
26	1.99	1.95	1.01	1.47	0.66	0.80	2.17	1.44
50	2.61	2.56	1.63	2.29	0.96	1.15	2.03	1.35
97	3.42	3.37	2.44	3.11	1.35	1.62	2.37	1.73
100	3.47	3.42	2.49	3.16	1.37	1.65	2.39	1.75
200	5.29	5.23	4.3	4.97	1.72	2.06	2.56	2.02
500	10.07	10	9.09	9.75	2.16	2.6	2.88	2.39
750	12.58	12.51	11.6	12.28	2.57	3.09	3.35	2.81

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-37. Adult *O. mykiss* passage performance at Murphy Flashboard Dam

Model	Depth (ft)				Velocity (ft/s)			
Flow (cfs)	channel 2	dam 2	dam1	channel 1	channel 2	dam 2	dam1	channel 1
1	1.13	1.09	0.16	0.44	0.06	0.07	1.27	1.09
3	1.22	1.18	0.24	0.56	0.15	0.18	2.24	1.68
5	1.31	1.26	0.31	0.67	0.24	0.28	3.2	2.26
10	1.49	1.44	0.59	1.05	0.39	0.47	2.52	1.14
20	1.84	1.8	0.85	1.27	0.59	0.71	2.21	1.46
26	1.99	1.95	1.01	1.47	0.66	0.80	2.17	1.44
50	2.61	2.56	1.63	2.29	0.96	1.15	2.03	1.35
100	3.47	3.42	2.49	3.16	1.37	1.65	2.39	1.75
166	4.67	4.61	3.68	4.35	1.60	1.92	2.50	1.93
200	5.29	5.23	4.3	4.97	1.72	2.06	2.56	2.02
500	10.07	10	9.09	9.75	2.16	2.6	2.88	2.39
750	12.58	12.51	11.6	12.28	2.57	3.09	3.35	2.81

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult O. mykiss

Table 5-38. Juvenile salmonid passage performance at Murphy Flashboard Dam

Model Flow (cfs)	Depth (ft) Channel 2	Depth (ft) Dam 2	Depth (ft) Dam1	Depth (ft) Channel 1	Velocity (ft/s) Channel 2	Velocity (ft/s) Dam 2	Velocity (ft/s) Dam1	Velocity (ft/s) Channel 1
1	1.13	1.09	0.16	0.44	0.06	0.07	1.27	1.09
3	1.22	1.18	0.24	0.56	0.15	0.18	2.24	1.68
5	1.31	1.26	0.31	0.67	0.24	0.28	3.2	2.26
8	1.42	1.37	0.50	0.90	0.33	0.39	2.79	1.59
10	1.49	1.44	0.59	1.05	0.39	0.47	2.52	1.14
20	1.84	1.8	0.85	1.27	0.59	0.71	2.21	1.46
38	2.30	2.26	1.32	1.88	0.81	0.97	2.10	1.39
50	2.61	2.56	1.63	2.29	0.96	1.15	2.03	1.35
100	3.47	3.42	2.49	3.16	1.37	1.65	2.39	1.75
166	4.67	4.61	3.68	4.35	1.60	1.92	2.50	1.93
200	5.29	5.23	4.3	4.97	1.72	2.06	2.56	2.02
500	10.07	10	9.09	9.75	2.16	2.6	2.88	2.39
750	12.58	12.51	11.6	12.28	2.57	3.09	3.35	2.81

indicates that depth criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-39. Adult Chinook passage performance at Clements Road Flashboard Dam

Model	Depth (ft)					Velocity (ft/s)				
Flow (cfs)	riprap 3	riprap 2	riprap 1	apron	crossing	riprap 3	riprap 2	riprap 1	apron	crossing
1	0.17	0.5	1.43	0.1	0.14	1.76	0.32	0.07	1.46	1.48
2.5	0.25	0.59	1.49	0.16	0.22	2.38	0.48	0.16	1.85	1.61
3	0.27	0.60	1.50	0.17	0.23	2.42	0.53	0.19	1.94	1.72
5	0.36	0.64	1.52	0.23	0.27	2.60	0.75	0.3	2.29	2.18
7.5	0.44	0.67	1.52	0.28	0.32	2.71	1.03	0.46	2.53	2.47
10	0.5	0.67	1.51	0.33	0.37	2.84	1.37	0.62	2.74	2.72
15	0.73	0.66	1.49	0.41	0.43	1.98	2.15	0.95	3	3.28
20	1.37	0.93	1.64	0.47	0.5	0.86	1.38	1.07	3.25	3.61
25	1.59	0.97	1.63	0.53	0.57	0.85	1.6	1.35	3.45	3.84
30	1.82	1.01	1.62	0.58	0.63	0.83	1.78	1.64	3.64	4.08
35	2.05	1.05	1.6	0.62	0.68	0.82	1.95	1.95	3.83	4.32
40	2.28	1.09	1.59	0.66	0.74	0.8	2.1	2.26	4.02	4.51
50	2.73	1.25	1.62	1.09	1.04	0.78	2.12	2.72	2.69	3.81
60	3.19	1.69	2.01	1.44	1.4	0.76	1.62	2.26	2.35	3.31
67	3.51	2.01	2.31	1.73	1.69	0.75	1.44	2.02	2.15	3.03
70	3.64	2.14	2.44	1.86	1.82	0.74	1.36	1.92	2.07	2.91
80	4.09	2.6	2.88	2.29	2.27	0.72	1.2	1.7	1.88	2.64
97	4.86	3.37	3.65	3.06	3.04	0.69	1.04	1.49	1.68	2.38
100	4.99	3.5	3.79	3.19	3.17	0.68	1.01	1.45	1.65	2.33
120	5.9	4.41	4.69	4.09	4.07	0.65	0.89	1.31	1.53	2.16
140	6.80	5.31	5.59	4.99	4.97	0.63	0.81	1.23	1.45	2.05
160	7.7	6.21	6.49	5.89	5.88	0.6	0.75	1.17	1.4	1.98
180	8.6	7.11	7.40	6.8	6.78	0.58	0.7	1.13	1.36	2.03
200	9.51	8.02	8.30	7.7	7.68	0.56	0.67	1.1	1.33	2.26
250	11.76	10.28	10.56	9.97	9.93	0.52	0.6	0.77	0.66	2.82
300	14.02	12.53	12.82	12.23	12.17	0.49	0.55	0.69	0.6	3.39
350	16.28	14.79	15.08	14.49	14.47	0.47	0.52	0.62	0.56	1.78
400	18.54	17.05	17.34	16.74	16.73	0.45	0.5	0.58	0.53	1.24
450	20.8	19.31	19.60	19	18.99	0.44	0.49	0.55	0.51	1
500	23.06	21.57	21.86	21.26	21.25	0.43	0.47	0.53	0.5	0.87

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-40. Adult *O. mykiss* passage performance at Clements Road Flashboard Dam

Model	Depth (ft)					Velocity (ft/s)				
Flow (cfs)	riprap 3	riprap 2	riprap 1	apron	crossing	riprap 3	riprap 2	riprap 1	apron	crossing
1	0.17	0.5	1.43	0.1	0.14	1.76	0.32	0.07	1.46	1.48
2.5	0.25	0.59	1.49	0.16	0.22	2.38	0.48	0.16	1.85	1.61
3	0.27	0.60	1.50	0.17	0.23	2.42	0.53	0.19	1.94	1.72
5	0.36	0.64	1.52	0.23	0.27	2.60	0.75	0.3	2.29	2.18
7.5	0.44	0.67	1.52	0.28	0.32	2.71	1.03	0.46	2.53	2.47
10	0.5	0.67	1.51	0.33	0.37	2.84	1.37	0.62	2.74	2.72
15	0.73	0.66	1.49	0.41	0.43	1.98	2.15	0.95	3	3.28
20	1.37	0.93	1.64	0.47	0.5	0.86	1.38	1.07	3.25	3.61
25	1.59	0.97	1.63	0.53	0.57	0.85	1.6	1.35	3.45	3.84
30	1.82	1.01	1.62	0.58	0.63	0.83	1.78	1.64	3.64	4.08
35	2.05	1.05	1.6	0.62	0.68	0.82	1.95	1.95	3.83	4.32
40	2.28	1.09	1.59	0.66	0.74	0.8	2.1	2.26	4.02	4.51
50	2.73	1.25	1.62	1.09	1.04	0.78	2.12	2.72	2.69	3.81
60	3.19	1.69	2.01	1.44	1.4	0.76	1.62	2.26	2.35	3.31
67	3.51	2.01	2.31	1.73	1.69	0.75	1.44	2.02	2.15	3.03
70	3.64	2.14	2.44	1.86	1.82	0.74	1.36	1.92	2.07	2.91
80	4.09	2.6	2.88	2.29	2.27	0.72	1.2	1.7	1.88	2.64
100	4.99	3.50	3.79	3.19	3.17	0.68	1.01	1.45	1.65	2.33
120	5.90	4.41	4.69	4.09	4.07	0.65	0.89	1.31	1.53	2.16
140	6.80	5.31	5.59	4.99	4.97	0.63	0.81	1.23	1.45	2.05
160	7.70	6.21	6.49	5.89	5.88	0.60	0.75	1.17	1.40	1.98
166	7.97	6.48	6.76	6.16	6.15	0.59	0.74	1.16	1.39	2.00
180	8.6	7.11	7.40	6.8	6.78	0.58	0.7	1.13	1.36	2.03
200	9.51	8.02	8.30	7.7	7.68	0.56	0.67	1.1	1.33	2.26
250	11.76	10.28	10.56	9.97	9.93	0.52	0.6	0.77	0.66	2.82
300	14.02	12.53	12.82	12.23	12.17	0.49	0.55	0.69	0.6	3.39
350	16.28	14.79	15.08	14.49	14.47	0.47	0.52	0.62	0.56	1.78
400	18.54	17.05	17.34	16.74	16.73	0.45	0.5	0.58	0.53	1.24
450	20.8	19.31	19.60	19	18.99	0.44	0.49	0.55	0.51	1
500	23.06	21.57	21.86	21.26	21.25	0.43	0.47	0.53	0.5	0.87

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-41. Juvenile salmonid passage performance at Clements Road Flashboard Dam

Model	Depth (ft)					Velocity (ft/s)				
Flow (cfs)	Riprap 3	Riprap 2	Riprap 1	Apron	Crossing	Riprap 3	Riprap 2	Riprap 1	Apron	Crossing
1	0.17	0.5	1.43	0.1	0.14	1.76	0.32	0.07	1.46	1.48
2.5	0.25	0.59	1.49	0.16	0.22	2.38	0.48	0.16	1.85	1.61
5	0.36	0.64	1.52	0.23	0.27	2.60	0.75	0.3	2.29	2.18
7.5	0.44	0.67	1.52	0.28	0.32	2.71	1.03	0.46	2.53	2.47
10	0.5	0.67	1.51	0.33	0.37	2.84	1.37	0.62	2.74	2.72
15	0.73	0.66	1.49	0.41	0.43	1.98	2.15	0.95	3	3.28
20	1.37	0.93	1.64	0.47	0.5	0.86	1.38	1.07	3.25	3.61
25	1.59	0.97	1.63	0.53	0.57	0.85	1.6	1.35	3.45	3.84
30	1.82	1.01	1.62	0.58	0.63	0.83	1.78	1.64	3.64	4.08
35	2.05	1.05	1.6	0.62	0.68	0.82	1.95	1.95	3.83	4.32
38	2.19	1.07	1.59	0.64	0.72	0.81	2.04	2.14	3.94	4.43
40	2.28	1.09	1.59	0.66	0.74	0.8	2.1	2.26	4.02	4.51
50	2.73	1.25	1.62	1.09	1.04	0.78	2.12	2.72	2.69	3.81
60	3.19	1.69	2.01	1.44	1.4	0.76	1.62	2.26	2.35	3.31
67	3.51	2.01	2.31	1.73	1.69	0.75	1.44	2.02	2.15	3.03
70	3.64	2.14	2.44	1.86	1.82	0.74	1.36	1.92	2.07	2.91
80	4.09	2.6	2.88	2.29	2.27	0.72	1.2	1.7	1.88	2.64
100	4.99	3.50	3.79	3.19	3.17	0.68	1.01	1.45	1.65	2.33
120	5.90	4.41	4.69	4.09	4.07	0.65	0.89	1.31	1.53	2.16
140	6.80	5.31	5.59	4.99	4.97	0.63	0.81	1.23	1.45	2.05
160	7.70	6.21	6.49	5.89	5.88	0.60	0.75	1.17	1.40	1.98
180	8.6	7.11	7.40	6.8	6.78	0.58	0.7	1.13	1.36	2.03
200	9.51	8.02	8.30	7.7	7.68	0.56	0.67	1.1	1.33	2.26
250	11.76	10.28	10.56	9.97	9.93	0.52	0.6	0.77	0.66	2.82
300	14.02	12.53	12.82	12.23	12.17	0.49	0.55	0.69	0.6	3.39
350	16.28	14.79	15.08	14.49	14.47	0.47	0.52	0.62	0.56	1.78
400	18.54	17.05	17.34	16.74	16.73	0.45	0.5	0.58	0.53	1.24
450	20.8	19.31	19.60	19	18.99	0.44	0.49	0.55	0.51	1
500	23.06	21.57	21.86	21.26	21.25	0.43	0.47	0.53	0.5	0.87

indicates that depth criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-42. Adult Chinook passage performance at Lavaggi Flashboard Dam

	Depth (ft)			Velocity (ft/s)		
Model Flow (cfs)	Riprap	Apron	Dam	Riprap	Apron	Dam
2	0.41	0.11	0.18	2.30	0.39	0.29
3	0.46	0.18	0.25	2.43	0.38	0.30
5	0.56	0.33	0.40	2.69	0.34	0.30
10	0.70	0.56	0.62	3.14	0.40	0.38
15	0.86	0.65	0.71	2.67	0.51	0.49
20	0.91	0.75	0.81	2.89	0.59	0.57
30	1.10	0.88	0.95	2.40	0.75	0.73
40	1.48	1.12	1.18	1.58	0.79	0.77
50	1.86	1.44	1.50	1.23	0.77	0.75
60	2.00	1.58	1.64	1.27	0.83	0.82
75	2.21	1.79	1.86	1.34	0.93	0.91
100	2.56	2.13	2.21	1.39	1.04	1.02
150	3.26	2.82	2.89	1.43	1.17	1.16
200	3.97	3.52	3.60	1.43	1.25	1.25
300	4.44	4.00	4.08	1.81	1.64	1.64
400	4.69	4.26	4.36	2.24	2.05	2.05
500	4.94	4.53	4.64	2.60	2.40	2.41
600	5.19	4.78	4.90	2.91	2.71	2.74
800	5.68	5.27	5.41	3.40	3.25	3.31
978	6.12	5.71	5.86	3.74	3.65	3.73
1000	6.17	5.76	5.92	3.78	3.70	3.79
1500	7.40	6.97	7.19	4.35	4.53	4.68
2000	8.64	8.19	8.36	4.61	4.88	5.23
2500	9.88	9.45	9.54	4.71	4.84	5.18
3000	11.11	10.71	10.79	4.73	4.77	5.04
3500	12.34	11.94	12.02	4.70	4.71	4.93
4000	13.57	13.17	13.26	4.66	4.64	4.83
4500	14.80	14.41	14.49	4.61	4.57	4.73
5000	16.03	15.64	15.72	4.55	4.50	4.64
5500	17.26	16.86	16.94	4.50	4.44	4.56

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult chinook

Table 5-43. Adult *O. mykiss* passage performance at Lavaggi Flashboard Dam

Model Flow (cfs)	Depth (ft)			Velocity (ft/s)		
	Riprap	Apron	Dam	Riprap	Apron	Dam
2	0.41	0.11	0.18	2.30	0.39	0.29
5	0.56	0.33	0.40	2.69	0.34	0.30
6	0.59	0.38	0.44	2.78	0.35	0.32
10	0.70	0.56	0.62	3.14	0.40	0.38
15	0.86	0.65	0.71	2.67	0.51	0.49
20	0.91	0.75	0.81	2.89	0.59	0.57
30	1.10	0.88	0.95	2.40	0.75	0.73
40	1.48	1.12	1.18	1.58	0.79	0.77
50	1.86	1.44	1.50	1.23	0.77	0.75
60	2.00	1.58	1.64	1.27	0.83	0.82
75	2.21	1.79	1.86	1.34	0.93	0.91
100	2.56	2.13	2.21	1.39	1.04	1.02
150	3.26	2.82	2.89	1.43	1.17	1.16
200	3.97	3.52	3.60	1.43	1.25	1.25
300	4.44	4.00	4.08	1.81	1.64	1.64
400	4.69	4.26	4.36	2.24	2.05	2.05
500	4.94	4.53	4.64	2.60	2.40	2.41
600	5.19	4.78	4.90	2.91	2.71	2.74
800	5.68	5.27	5.41	3.40	3.25	3.31
1000	6.17	5.76	5.92	3.78	3.70	3.79
1500	7.40	6.97	7.19	4.35	4.53	4.68
2000	8.64	8.19	8.36	4.61	4.88	5.23
2500	9.88	9.45	9.54	4.71	4.84	5.18
3000	11.11	10.71	10.79	4.73	4.77	5.04
3500	12.34	11.94	12.02	4.70	4.71	4.93
4000	13.57	13.17	13.26	4.66	4.64	4.83
4500	14.80	14.41	14.49	4.61	4.57	4.73
4540	14.90	14.51	14.59	4.61	4.57	4.72
5000	16.03	15.64	15.72	4.55	4.50	4.64
5500	17.26	16.86	16.94	4.50	4.44	4.56

(blue)	indicates that depth criteria are met at the section
(green)	indicates that velocity criteria are met at the section
(red box)	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Table 5-44. Juvenile salmonid passage performance at Lavaggi Flashboard Dam

	Depth (ft)			Velocity (ft/s)		
Model Flow (cfs)	Riprap	Apron	Dam	Riprap	Apron	Dam
1	0.36	0.04	0.11	2.17	0.41	0.29
2	0.41	0.11	0.18	2.30	0.39	0.29
5	0.56	0.33	0.40	2.69	0.34	0.30
10	0.70	0.56	0.62	3.14	0.40	0.38
15	0.86	0.65	0.71	2.67	0.51	0.49
20	0.91	0.75	0.81	2.89	0.59	0.57
25	1.00	0.81	0.88	2.66	0.67	0.64
30	1.10	0.88	0.95	2.40	0.75	0.73
40	1.48	1.12	1.18	1.58	0.79	0.77
50	1.86	1.44	1.50	1.23	0.77	0.75
75	2.21	1.79	1.86	1.34	0.93	0.91
100	2.56	2.13	2.21	1.39	1.04	1.02
150	3.26	2.82	2.89	1.43	1.17	1.16
200	3.97	3.52	3.60	1.43	1.25	1.25
300	4.44	4.00	4.08	1.81	1.64	1.64
400	4.69	4.26	4.36	2.24	2.05	2.05
500	4.94	4.53	4.64	2.60	2.40	2.41
600	5.19	4.78	4.90	2.91	2.71	2.74
800	5.68	5.27	5.41	3.40	3.25	3.31
847	5.80	5.39	5.53	3.49	3.36	3.42
1000	6.17	5.76	5.92	3.78	3.70	3.79
1500	7.40	6.97	7.19	4.35	4.53	4.68
2000	8.64	8.19	8.36	4.61	4.88	5.23
2500	9.88	9.45	9.54	4.71	4.84	5.18
3000	11.11	10.71	10.79	4.73	4.77	5.04
3500	12.34	11.94	12.02	4.70	4.71	4.93
4000	13.57	13.17	13.26	4.66	4.64	4.83
4500	14.80	14.41	14.49	4.61	4.57	4.73
5000	16.03	15.64	15.72	4.55	4.50	4.64
5500	17.26	16.86	16.94	4.50	4.44	4.56

	indicates that depth criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonid

Table 5-45. Adult Chinook passage performance at Fujinaka Low Flow Road Crossing

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	Channel 1	Riprap	Culvert 1	Culvert 2	Culvert 3	Crossing	Channel 1	Riprap	Culvert 1	Culvert 2	Culvert 3	Crossing
2	0.39	2.26	1.48	0.29			0.88	0.06	0.37	1.19		
3	0.45	2.32	1.54	0.35			0.96	0.08	0.55	1.02		
5	0.56	2.43	1.66	0.46			1.12	0.12	0.91	0.69		
10	0.73	2.62	1.85	0.65			1.37	0.22	1.44	1.49		
15	0.86	2.76	1.99	0.79			1.53	0.3	1.82	2.24		
20	0.97	2.88	2.11	0.91	0.06		1.63	0.37	2.23	2.55	0.6	
22	1.00	2.9	2.1	0.9	0.1		1.7	0.4	2.4	2.7	0.8	
25	1.06	3.0	2.2	1.0	0.2		1.7	0.4	2.6	2.9	1.2	
30	1.14	3.06	2.29	1.09	0.25		1.82	0.5	2.88	3.16	1.83	
40	1.27	3.21	2.44	1.24	0.43		2	0.61	3.44	3.64	2.46	
50	1.39	3.34	2.57	1.37	0.56		2.13	0.71	3.92	4.07	2.93	
75	1.64	3.61	2.84	1.65	0.89		2.37	0.93	4.9	4.97	3.81	
84	1.72	3.7	2.9	1.7	1.00		2.4	1.0	5.2	5.2	4.0	
100	1.85	3.84	3.07	1.89	1.2		2.55	1.12	5.75	5.72	4.33	
150	2.16	4.18	3.41	2.32	1.66		2.91	1.45	7.27	7.02	5.58	
178	2.31	4.35	3.58	2.5	1.8		3.06	1.60	8.00	7.89	6.39	
181	2.33	4.37	3.60	2.5	1.8		3.07	1.62	8.08	7.99	6.48	
200	2.43	4.48	3.71	2.64	1.96		3.17	1.72	8.58	8.58	7.03	
300	3.41	5.39	4	3.5	2.5	0.71	2.71	1.93	8.98	8.8	6.58	1.94
367	3.71	5.70	4	3.5	2.5	1.00	2.87	2.16	8.95	8.77	6.57	2.34
400	3.86	5.85	4	3.5	2.5	1.14	2.95	2.27	8.94	8.75	6.56	2.53
500	4.24	6.24	4	3.5	2.5	1.50	3.17	2.57	8.56	8.44	6.29	2.94
600	4.56	6.58	4	3.5	2.5	1.80	3.39	2.84	8.41	8.28	6.17	3.22
740	4.97	7.00	4	3.5	2.5	2.15	3.64	3.16	8.12	8.00	5.97	3.52
800	5.15	7.18	4	3.5	2.5	2.30	3.75	3.29	7.99	7.88	5.88	3.65
978	5.62	7.67	4	3.5	2.5	2.68	4.02	3.59	7.62	7.53	5.62	3.92
1000	5.68	7.73	4	3.5	2.5	2.73	4.05	3.63	7.57	7.49	5.59	3.96
1500	6.83	8.92	4	3.5	2.5	3.61	4.67	4.1	6.44	6.37	4.72	4.57
2000	7.83	9.97	4	3.5	2.5	4.41	5.14	4.36	5.46	5.41	4.02	4.96
2500	8.72	10.9	4	3.5	2.5	5.22	5.54	4.58	4.81	4.74	3.31	5.16
3000	9.54	11.76	4	3.5	2.5	6.05	5.87	4.77	4.7	4.62	2.96	5.22
3500	10.3	12.55	4	3.5	2.5	6.85	6.17	4.95	4.63	4.56	2.69	5.27
4000	11.02	13.3	4	3.5	2.5	7.63	6.43	5.1	4.82	4.74	2.8	5.30
4500	11.69	14	4	3.5	2.5	8.35	6.67	5.25	4.88	4.8	2.72	5.36
5000	12.33	14.67	4	3.5	2.5	9.04	6.89	5.38	5.06	4.98	2.85	5.39
5500	12.94	15.3	4	3.5	2.5	9.71	7.1	5.51	5.2	5.11	2.92	5.52

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-46. Adult *O. mykiss* passage performance at Fujinaka Low Flow Road Crossing

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	Channel 1	Riprap	Culvert 1	Culvert 2	Culvert 3	Crossing	Channel 1	Riprap	Culvert 1	Culvert 2	Culvert 3	Crossing
2	0.39	2.26	1.48	0.29			0.88	0.06	0.37	1.19		
5	0.56	2.43	1.66	0.46			1.12	0.12	0.91	0.69		
6	0.59	2.47	1.70	0.50			1.17	0.14	1.02	0.85		
10	0.73	2.62	1.85	0.65			1.37	0.22	1.44	1.49		
15	0.86	2.76	1.99	0.79			1.53	0.3	1.82	2.24		
20	0.97	2.88	2.11	0.91	0.06		1.63	0.37	2.23	2.55	0.6	
22	1.00	2.9	2.1	0.9	0.1		1.7	0.4	2.4	2.7	0.8	
25	1.06	3.0	2.2	1.0	0.2		1.7	0.4	2.6	2.9	1.2	
30	1.14	3.06	2.29	1.09	0.25		1.82	0.5	2.88	3.16	1.83	
40	1.27	3.21	2.44	1.24	0.43		2	0.61	3.44	3.64	2.46	
50	1.39	3.34	2.57	1.37	0.56		2.13	0.71	3.92	4.07	2.93	
75	1.64	3.61	2.84	1.65	0.89		2.37	0.93	4.9	4.97	3.81	
84	1.72	3.7	2.9	1.7	1.00		2.4	1.0	5.2	5.2	4.0	
100	1.85	3.84	3.07	1.89	1.2		2.55	1.12	5.75	5.72	4.33	
150	2.16	4.18	3.41	2.32	1.66		2.91	1.45	7.27	7.02	5.58	
178	2.31	4.35	3.58	2.5	1.8		3.06	1.60	8.00	7.89	6.39	
181	2.33	4.37	3.60	2.5	1.8		3.07	1.62	8.08	7.99	6.48	
200	2.43	4.48	3.71	2.64	1.96		3.17	1.72	8.58	8.58	7.03	
300	3.41	5.39	4	3.5	2.5	0.71	2.71	1.93	8.98	8.8	6.58	1.94
367	3.71	5.70	4	3.5	2.5	1.00	2.87	2.16	8.95	8.77	6.57	2.34
400	3.86	5.85	4	3.5	2.5	1.14	2.95	2.27	8.94	8.75	6.56	2.53
500	4.24	6.24	4	3.5	2.5	1.50	3.17	2.57	8.56	8.44	6.29	2.94
600	4.56	6.58	4	3.5	2.5	1.80	3.39	2.84	8.41	8.28	6.17	3.22
740	4.97	7.00	4	3.5	2.5	2.15	3.64	3.16	8.12	8.00	5.97	3.52
800	5.15	7.18	4	3.5	2.5	2.30	3.75	3.29	7.99	7.88	5.88	3.65
1000	5.68	7.73	4	3.5	2.5	2.73	4.05	3.63	7.57	7.49	5.59	3.96
1500	6.83	8.92	4	3.5	2.5	3.61	4.67	4.1	6.44	6.37	4.72	4.57
2000	7.83	9.97	4	3.5	2.5	4.41	5.14	4.36	5.46	5.41	4.02	4.96
2500	8.72	10.9	4	3.5	2.5	5.22	5.54	4.58	4.81	4.74	3.31	5.16
3000	9.54	11.76	4	3.5	2.5	6.05	5.87	4.77	4.7	4.62	2.96	5.22
3500	10.3	12.55	4	3.5	2.5	6.85	6.17	4.95	4.63	4.56	2.69	5.27
4000	11.02	13.3	4	3.5	2.5	7.63	6.43	5.1	4.82	4.74	2.8	5.30
4500	11.69	14	4	3.5	2.5	8.35	6.67	5.25	4.88	4.8	2.72	5.36
4540	11.74	14.05	4	3.5	2.5	8.41	6.69	5.26	4.89	4.81	2.73	5.36
5000	12.33	14.67	4	3.5	2.5	9.04	6.89	5.38	5.06	4.98	2.85	5.39
5500	12.94	15.3	4	3.5	2.5	9.71	7.1	5.51	5.2	5.11	2.92	5.52

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-47. Juvenile salmonid passage performance at Fujinaka Low Flow Road Crossing

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	Channel 1	Riprap	Culvert 1	Culvert 2	Culvert 3	Crossing	Channel 1	Riprap	Culvert 1	Culvert 2	Culvert 3	Crossing
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	0.39	2.26	1.48	0.29			0.88	0.06	0.37	1.19		
4	0.50	2.37	1.60	0.40			1.04	0.10	0.73	0.86		
5	0.56	2.43	1.66	0.46			1.12	0.12	0.91	0.69		
6	0.59	2.47	1.70	0.50			1.17	0.14	1.02	0.85		
10	0.73	2.62	1.85	0.65			1.37	0.22	1.44	1.49		
15	0.86	2.76	1.99	0.79			1.53	0.3	1.82	2.24		
20	0.97	2.88	2.11	0.91	0.06		1.63	0.37	2.23	2.55	0.6	
30	1.14	3.06	2.29	1.09	0.25		1.82	0.5	2.88	3.16	1.83	
40	1.27	3.21	2.44	1.24	0.43		2	0.61	3.44	3.64	2.46	
45	1.33	3.3	2.5	1.3	0.50		2.1	0.7	3.7	3.9	2.7	
50	1.39	3.34	2.57	1.37	0.56		2.13	0.71	3.92	4.07	2.93	
75	1.64	3.61	2.84	1.65	0.89		2.37	0.93	4.9	4.97	3.81	
100	1.85	3.84	3.07	1.89	1.2		2.55	1.12	5.75	5.72	4.33	
150	2.16	4.18	3.41	2.32	1.66		2.91	1.45	7.27	7.02	5.58	
200	2.43	4.48	3.71	2.64	1.96		3.17	1.72	8.58	8.58	7.03	
300	3.41	5.39	4	3.5	2.5	0.71	2.71	1.93	8.98	8.8	6.58	1.94
400	3.86	5.85	4	3.5	2.5	1.14	2.95	2.27	8.94	8.75	6.56	2.53
500	4.24	6.24	4	3.5	2.5	1.50	3.17	2.57	8.56	8.44	6.29	2.94
600	4.56	6.58	4	3.5	2.5	1.80	3.39	2.84	8.41	8.28	6.17	3.22
800	5.15	7.18	4	3.5	2.5	2.30	3.75	3.29	7.99	7.88	5.88	3.65
847	5.27	7.31	4	3.5	2.5	2.40	3.82	3.37	7.89	7.79	5.81	3.72
1000	5.68	7.73	4	3.5	2.5	2.73	4.05	3.63	7.57	7.49	5.59	3.96
1500	6.83	8.92	4	3.5	2.5	3.61	4.67	4.1	6.44	6.37	4.72	4.57
2000	7.83	9.97	4	3.5	2.5	4.41	5.14	4.36	5.46	5.41	4.02	4.96
2500	8.72	10.9	4	3.5	2.5	5.22	5.54	4.58	4.81	4.74	3.31	5.16
3000	9.54	11.76	4	3.5	2.5	6.05	5.87	4.77	4.7	4.62	2.96	5.22
3500	10.3	12.55	4	3.5	2.5	6.85	6.17	4.95	4.63	4.56	2.69	5.27
4000	11.02	13.3	4	3.5	2.5	7.63	6.43	5.1	4.82	4.74	2.8	5.30
4500	11.69	14	4	3.5	2.5	8.35	6.67	5.25	4.88	4.8	2.72	5.36
5000	12.33	14.67	4	3.5	2.5	9.04	6.89	5.38	5.06	4.98	2.85	5.39
5500	12.94	15.3	4	3.5	2.5	9.71	7.1	5.51	5.2	5.11	2.92	5.52

indicates that depth criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-48. Adult Chinook passage performance at Mormon Slough Railroad Bridge

	Depth (ft)							Velocity (ft/s)						
Model Flow (cfs)	Bridge DS Bay 1	Bridge DS Bay 2	Bridge US Bay 3	Bridge US Bay 4	Bridge US Bay 5	Apron DS	Apron US	Bridge DS Bay 1	Bridge DS Bay 2	Bridge US Bay 3	Bridge US Bay 4	Bridge US Bay 5	Apron DS	Apron US
2			0.34			0.71	0.36			2.31			0.63	2.07
5			0.47	0.12		0.88	0.49			2.93	1.46		1.09	2.77
10			0.63	0.28		0.67	0.65			3.38	2.12		3.53	3.27
15			0.74	0.33		0.80	0.77			3.77	2.58		3.91	3.54
20			0.83	0.44		0.93	0.86			4.01	2.72		4.01	3.79
30			0.98	0.60		1.12	1.02			4.33	3.14		4.14	4.05
32			1.00	0.62		1.14	1.04			4.35	3.19		4.16	4.09
40			1.11	0.75		1.26	1.14			4.48	3.44		4.28	4.31
50		0.13	1.22	0.85		1.38	1.25		0.54	4.66	3.69		4.39	4.50
75		0.32	1.42	1.05		2.03	1.54		1.27	5.15	4.10		2.87	4.25
100		0.52	1.56	1.21		2.17	1.76		1.98	5.44	4.45		3.35	4.10
150		0.77	1.81	1.46		2.39	2.07		2.74	5.83	4.89		4.03	4.15
200		0.98	2.01	1.67		2.57	2.31		3.21	6.10	5.20		4.56	4.27
300		1.29	2.38	2.01		2.93	2.69		3.81	6.33	5.67		5.01	4.50
400		1.55	2.70	2.30		3.27	2.99		4.25	6.42	5.88		5.13	4.70
500		1.78	2.97	2.57		3.56	3.25		4.59	6.47	6.01		5.28	4.87
600		1.98	3.20	2.80		3.79	3.48		4.88	6.58	6.13		5.45	5.01
800		2.33	3.55	3.14		4.12	3.86		5.34	6.95	6.59		5.99	5.30
802		2.33	3.55	3.14		4.12	3.86		5.34	6.96	6.60		6.00	5.30
1000		2.62	3.78	3.39		4.28	4.18		5.71	7.55	7.06		6.90	5.55
1500		3.26	4.38	3.99	0.24	4.77	4.85		6.42	8.11	7.67	1.89	8.03	6.03
1590		3.35	4.48	4.08	0.33	4.90	4.94		6.52	8.16	7.75	2.16	7.97	6.12
2000		3.75	4.91	4.48	0.74	5.47	5.35		6.97	8.39	8.11	3.40	7.71	6.53
2500	0.26	4.19	5.78	5.33	1.38	6.47	5.95	1.04	7.62	7.38	7.14	2.89	6.45	6.55
3000	0.90	4.86	6.87	6.40	2.24	7.54	6.91	2.77	8.12	6.01	5.85	2.33	5.50	5.78
3500	1.74	6.42	7.94	7.36	3.18	8.63	8.02	3.91	5.62	5.34	5.78	2.61	4.66	4.86
4000	2.72	7.65	9.04	8.30	4.21	9.73	9.12	4.16	4.20	4.82	6.23	2.43	4.11	4.30
4500	3.65	8.79	10.17	9.40	5.28	10.85	10.22	5.20	3.61	4.37	6.04	2.32	3.72	3.92
5000	4.77	9.92	11.31	10.51	6.38	11.98	11.35	5.02	3.19	3.99	5.92	2.16	3.44	3.63
5500	5.93	11.06	12.44	11.65	7.50	13.11	12.48	4.68	2.86	3.75	5.73	2.04	3.22	3.40

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult chinook

Table 5-49. Adult *O. mykiss* passage performance at Mormon Slough Railroad Bridge

	Depth (ft)							Velocity (ft/s)						
Model Flow (cfs)	Bridge DS Bay 1	Bridge DS Bay 2	Bridge US Bay 3	Bridge US Bay 4	Bridge US Bay 5	Apron DS	Apron US	Bridge DS Bay 1	Bridge DS Bay 2	Bridge US Bay 3	Bridge US Bay 4	Bridge US Bay 5	Apron DS	Apron US
2			0.34			0.71	0.36			2.31			0.63	2.07
5			0.47	0.12		0.88	0.49			2.93	1.46		1.09	2.77
10			0.63	0.28		0.67	0.65			3.38	2.12		3.53	3.27
15			0.74	0.33		0.80	0.77			3.77	2.58		3.91	3.54
19			0.81	0.42		0.90	0.84			3.96	2.69		3.99	3.74
20			0.83	0.44		0.93	0.86			4.01	2.72		4.01	3.79
30			0.98	0.60		1.12	1.02			4.33	3.14		4.14	4.05
32			1.00	0.62		1.14	1.04			4.35	3.19		4.16	4.09
40			1.11	0.75		1.26	1.14			4.48	3.44		4.28	4.31
50		0.13	1.22	0.85		1.38	1.25		0.54	4.66	3.69		4.39	4.50
75		0.32	1.42	1.05		2.03	1.54		1.27	5.15	4.10		2.87	4.25
100		0.52	1.56	1.21		2.17	1.76		1.98	5.44	4.45		3.35	4.10
150		0.77	1.81	1.46		2.39	2.07		2.74	5.83	4.89		4.03	4.15
200		0.98	2.01	1.67		2.57	2.31		3.21	6.10	5.20		4.56	4.27
300		1.29	2.38	2.01		2.93	2.69		3.81	6.33	5.67		5.01	4.50
400		1.55	2.70	2.30		3.27	2.99		4.25	6.42	5.88		5.13	4.70
500		1.78	2.97	2.57		3.56	3.25		4.59	6.47	6.01		5.28	4.87
600		1.98	3.20	2.80		3.79	3.48		4.88	6.58	6.13		5.45	5.01
800		2.33	3.55	3.14		4.12	3.86		5.34	6.95	6.59		5.99	5.30
802		2.33	3.55	3.14		4.12	3.86		5.34	6.96	6.60		6.00	5.30
1000		2.62	3.78	3.39		4.28	4.18		5.71	7.55	7.06		6.90	5.55
1500		3.26	4.38	3.99	0.24	4.77	4.85		6.42	8.11	7.67	1.89	8.03	6.03
2000		3.75	4.91	4.48	0.74	5.47	5.35		6.97	8.39	8.11	3.40	7.71	6.53
2500	0.26	4.19	5.78	5.33	1.38	6.47	5.95	1.04	7.62	7.38	7.14	2.89	6.45	6.55
2857	0.72	4.67	6.56	6.09	1.99	7.23	6.64	2.28	7.98	6.40	6.22	2.49	5.77	6.00
3000	0.90	4.86	6.87	6.40	2.24	7.54	6.91	2.77	8.12	6.01	5.85	2.33	5.50	5.78
3500	1.74	6.42	7.94	7.36	3.18	8.63	8.02	3.91	5.62	5.34	5.78	2.61	4.66	4.86
4000	2.72	7.65	9.04	8.30	4.21	9.73	9.12	4.16	4.20	4.82	6.23	2.43	4.11	4.30
4500	3.65	8.79	10.17	9.40	5.28	10.85	10.22	5.20	3.61	4.37	6.04	2.32	3.72	3.92
5000	4.77	9.92	11.31	10.51	6.38	11.98	11.35	5.02	3.19	3.99	5.92	2.16	3.44	3.63
5460	5.84	10.97	12.35	11.56	7.41	13.02	12.39	4.71	2.89	3.77	5.75	2.05	3.24	3.42
5500	5.93	11.06	12.44	11.65	7.50	13.11	12.48	4.68	2.86	3.75	5.73	2.04	3.22	3.40

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Table 5-50. Juvenile salmonid passage performance at Mormon Slough Railroad Bridge

	Depth (ft)							Velocity (ft/s)						
Model Flow (cfs)	Bridge DS Bay 1	Bridge DS Bay 2	Bridge US Bay 3	Bridge US Bay 4	Bridge US Bay 5	Apron DS	Apron US	Bridge DS Bay 1	Bridge DS Bay 2	Bridge US Bay 3	Bridge US Bay 4	Bridge US Bay 5	Apron DS	Apron US
1			0.30			0.65	0.32			2.10			0.48	1.84
2			0.34			0.71	0.36			2.31			0.63	2.07
5			0.47	0.12		0.88	0.49			2.93	1.46		1.09	2.77
6			0.50	0.15		0.84	0.52			3.01	1.58		1.55	2.86
10			0.63	0.28		0.67	0.65			3.38	2.12		3.53	3.27
15			0.74	0.33		0.80	0.77			3.77	2.58		3.91	3.54
20			0.83	0.44		0.93	0.86			4.01	2.72		4.01	3.79
30			0.98	0.60		1.12	1.02			4.33	3.14		4.14	4.05
40			1.11	0.75		1.26	1.14			4.48	3.44		4.28	4.31
50		0.13	1.22	0.85		1.38	1.25		0.54	4.66	3.69		4.39	4.50
75		0.32	1.42	1.05		2.03	1.54		1.27	5.15	4.10		2.87	4.25
100		0.52	1.56	1.21		2.17	1.76		1.98	5.44	4.45		3.35	4.10
150		0.77	1.81	1.46		2.39	2.07		2.74	5.83	4.89		4.03	4.15
200		0.98	2.01	1.67		2.57	2.31		3.21	6.10	5.20		4.56	4.27
300		1.29	2.38	2.01		2.93	2.69		3.81	6.33	5.67		5.01	4.50
400		1.55	2.70	2.30		3.27	2.99		4.25	6.42	5.88		5.13	4.70
500		1.78	2.97	2.57		3.56	3.25		4.59	6.47	6.01		5.28	4.87
600		1.98	3.20	2.80		3.79	3.48		4.88	6.58	6.13		5.45	5.01
800		2.33	3.55	3.14		4.12	3.86		5.34	6.95	6.59		5.99	5.30
1000		2.62	3.78	3.39		4.28	4.18		5.71	7.55	7.06		6.90	5.55
1248		2.94	4.08	3.69	0.00	4.52	4.51		6.06	7.83	7.36	0.00	7.46	5.79
1500		3.26	4.38	3.99	0.24	4.77	4.85		6.42	8.11	7.67	1.89	8.03	6.03
2000		3.75	4.91	4.48	0.74	5.47	5.35		6.97	8.39	8.11	3.40	7.71	6.53
2500	0.26	4.19	5.78	5.33	1.38	6.47	5.95	1.04	7.62	7.38	7.14	2.89	6.45	6.55
3000	0.90	4.86	6.87	6.40	2.24	7.54	6.91	2.77	8.12	6.01	5.85	2.33	5.50	5.78
3500	1.74	6.42	7.94	7.36	3.18	8.63	8.02	3.91	5.62	5.34	5.78	2.61	4.66	4.86
4000	2.72	7.65	9.04	8.30	4.21	9.73	9.12	4.16	4.20	4.82	6.23	2.43	4.11	4.30
4500	3.65	8.79	10.17	9.40	5.28	10.85	10.22	5.20	3.61	4.37	6.04	2.32	3.72	3.92
5000	4.77	9.92	11.31	10.51	6.38	11.98	11.35	5.02	3.19	3.99	5.92	2.16	3.44	3.63
5500	5.93	11.06	12.44	11.65	7.50	13.11	12.48	4.68	2.86	3.75	5.73	2.04	3.22	3.40

	indicates that depth criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonid

Table 5-51. Adult Chinook passage performance at Piazza Flashboard Dam

Model	Depth (ft)							Velocity (ft/s)						
Flow (cfs)	Channel 1	Channel 2	Channel 3	Riprap 1	Riprap 2	Riprap 3	Dam	Channel 1	Channel 2	Channel 3	Riprap 1	Riprap 2	Riprap 3	Dam
2	0.46	0.5	0.29	0.55	0.11	0.74	0.11	0.33	0.25	2.17	2.97	0.72	0.17	0.63
5	0.63	0.6	0.44	0.79	0.18	0.83	0.2	0.48	0.42	1.89	3.57	0.92	0.35	0.81
10	0.9	0.7	0.51	1.06	0.27	0.93	0.3	0.57	0.58	1.94	3.75	1.05	0.56	1.02
15	1.18	0.79	0.54	1.22	0.34	1	0.38	0.59	0.69	2.13	3.95	1.16	0.72	1.16
20	1.46	0.87	0.58	1.42	0.4	1.06	0.44	0.6	0.77	2.14	3.14	1.27	0.85	1.27
30	2.01	1.02	0.62	1.54	0.49	1.19	0.57	0.6	0.87	2.49	3.13	1.47	1.04	1.42
40	2.57	1.14	0.67	1.61	0.56	1.28	0.67	0.58	0.98	2.61	3.28	1.67	1.22	1.57
50	2.64	1.25	0.7	1.67	0.63	1.37	0.77	0.7	1.06	2.8	3.49	1.83	1.35	1.67
75	2.83	1.48	0.84	1.8	0.77	1.57	0.98	0.96	1.24	2.72	3.81	2.18	1.63	1.89
100	3.01	1.68	0.99	1.9	0.89	1.74	1.16	1.18	1.38	2.59	4.13	2.47	1.84	2.05
114	3.11	1.78	1.07	2.00	0.91	1.82	1.25	1.28	1.44	2.57	3.97	2.73	1.93	2.13
150	3.38	2.03	1.27	2.27	0.96	2.04	1.48	1.53	1.61	2.51	3.55	3.39	2.16	2.33
200	3.8	2.32	1.53	2.76	1.06	2.3	1.76	1.76	1.8	2.51	2.97	4.06	2.42	2.54
300	4.75	2.83	1.99	3.76	1.76	2.77	2.26	1.96	2.1	2.6	2.44	3.54	2.8	2.89
330	5.01	3.00	2.14	4.02	2.00	2.94	2.43	1.99	2.15	2.60	2.39	3.43	2.83	2.93
400	5.61	3.38	2.48	4.63	2.57	3.33	2.83	2.06	2.25	2.61	2.28	3.17	2.89	3.02
500	6.26	3.98	3.01	5.29	3.22	3.97	3.46	2.18	2.3	2.55	2.31	3.15	2.86	3.04
600	6.83	4.52	3.52	5.87	3.78	4.53	4.03	2.28	2.37	2.53	2.36	3.2	2.87	3.10
800	7.81	5.49	4.46	6.86	4.76	5.53	5.04	2.47	2.49	2.55	2.48	3.37	2.93	3.27
1000	8.63	6.34	5.29	7.69	5.58	6.4	5.91	2.63	2.61	2.61	2.62	3.59	3.03	3.47
1500	10.28	8.06	7	9.36	7.23	8.12	7.66	3	2.92	2.83	2.96	4.14	3.37	3.97
1590	10.54	8.32	7.26	9.62	7.49	8.38	7.92	3.05	2.97	2.87	3.01	4.04	3.40	4.00
2000	11.71	9.5	8.44	10.8	8.7	9.57	9.13	3.29	3.18	3.04	3.21	3.59	3.53	4.11
2500	12.97	10.77	9.71	12.07	9.97	10.84	10.42	3.52	3.4	3.22	3.4	3.73	3.73	4.20
3000	14.15	11.96	10.91	13.25	11.16	12.04	11.64	3.7	3.57	3.36	3.55	3.84	3.86	4.26
3500	15.21	13.01	11.97	14.32	12.23	13.1	12.72	3.87	3.74	3.5	3.69	3.95	3.99	4.34
4000	16.18	13.99	12.95	15.3	13.2	14.09	13.71	4.03	3.89	3.63	3.82	4.06	4.1	4.40
4500	17.13	14.93	13.9	16.26	14.16	15.04	14.68	4.16	4.01	3.73	3.92	4.14	4.17	4.43
5000	18.12	15.9	14.87	17.25	15.16	16.01	15.66	4.24	4.09	3.78	3.98	4.18	4.19	4.43
5500	19.09	16.86	15.84	18.22	16.12	16.99	16.63	4.29	4.14	3.81	4.03	4.2	4.2	4.41

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-52. Adult *O. mykiss* passage performance at Piazza Flashboard Dam

Model	Depth (ft)							Velocity (ft/s)						
Flow (cfs)	Channel 1	Channel 2	Channel 3	Riprap 1	Riprap 2	Riprap 3	Dam	Channel 1	Channel 2	Channel 3	Riprap 1	Riprap 2	Riprap 3	Dam
2	0.46	0.5	0.29	0.55	0.11	0.74	0.11	0.33	0.25	2.17	2.97	0.72	0.17	0.63
5	0.63	0.6	0.44	0.79	0.18	0.83	0.2	0.48	0.42	1.89	3.57	0.92	0.35	0.81
10	0.9	0.7	0.51	1.06	0.27	0.93	0.3	0.57	0.58	1.94	3.75	1.05	0.56	1.02
15	1.18	0.79	0.54	1.22	0.34	1	0.38	0.59	0.69	2.13	3.95	1.16	0.72	1.16
19	1.40	0.85	0.57	1.38	0.39	1.05	0.43	0.60	0.75	2.14	3.30	1.25	0.82	1.25
20	1.46	0.87	0.58	1.42	0.4	1.06	0.44	0.6	0.77	2.14	3.14	1.27	0.85	1.27
30	2.01	1.02	0.62	1.54	0.49	1.19	0.57	0.6	0.87	2.49	3.13	1.47	1.04	1.42
40	2.57	1.14	0.67	1.61	0.56	1.28	0.67	0.58	0.98	2.61	3.28	1.67	1.22	1.57
50	2.64	1.25	0.7	1.67	0.63	1.37	0.77	0.7	1.06	2.8	3.49	1.83	1.35	1.67
75	2.83	1.48	0.84	1.8	0.77	1.57	0.98	0.96	1.24	2.72	3.81	2.18	1.63	1.89
100	3.01	1.68	0.99	1.9	0.89	1.74	1.16	1.18	1.38	2.59	4.13	2.47	1.84	2.05
114	3.11	1.78	1.07	2.00	0.91	1.82	1.25	1.28	1.44	2.57	3.97	2.73	1.93	2.13
150	3.38	2.03	1.27	2.27	0.96	2.04	1.48	1.53	1.61	2.51	3.55	3.39	2.16	2.33
170	3.55	2.15	1.37	2.47	1.00	2.14	1.59	1.62	1.69	2.51	3.32	3.66	2.26	2.41
200	3.8	2.32	1.53	2.76	1.06	2.3	1.76	1.76	1.8	2.51	2.97	4.06	2.42	2.54
300	4.75	2.83	1.99	3.76	1.76	2.77	2.26	1.96	2.1	2.6	2.44	3.54	2.8	2.89
330	5.01	3.00	2.14	4.02	2.00	2.94	2.43	1.99	2.15	2.60	2.39	3.43	2.83	2.93
400	5.61	3.38	2.48	4.63	2.57	3.33	2.83	2.06	2.25	2.61	2.28	3.17	2.89	3.02
500	6.26	3.98	3.01	5.29	3.22	3.97	3.46	2.18	2.3	2.55	2.31	3.15	2.86	3.04
600	6.83	4.52	3.52	5.87	3.78	4.53	4.03	2.28	2.37	2.53	2.36	3.2	2.87	3.10
800	7.81	5.49	4.46	6.86	4.76	5.53	5.04	2.47	2.49	2.55	2.48	3.37	2.93	3.27
1000	8.63	6.34	5.29	7.69	5.58	6.4	5.91	2.63	2.61	2.61	2.62	3.59	3.03	3.47
1500	10.28	8.06	7	9.36	7.23	8.12	7.66	3	2.92	2.83	2.96	4.14	3.37	3.97
2000	11.71	9.5	8.44	10.8	8.7	9.57	9.13	3.29	3.18	3.04	3.21	3.59	3.53	4.11
2500	12.97	10.77	9.71	12.07	9.97	10.84	10.42	3.52	3.4	3.22	3.4	3.73	3.73	4.20
3000	14.15	11.96	10.91	13.25	11.16	12.04	11.64	3.7	3.57	3.36	3.55	3.84	3.86	4.26
3500	15.21	13.01	11.97	14.32	12.23	13.1	12.72	3.87	3.74	3.5	3.69	3.95	3.99	4.34
4000	16.18	13.99	12.95	15.3	13.2	14.09	13.71	4.03	3.89	3.63	3.82	4.06	4.1	4.40
4500	17.13	14.93	13.9	16.26	14.16	15.04	14.68	4.16	4.01	3.73	3.92	4.14	4.17	4.43
5000	18.12	15.9	14.87	17.25	15.16	16.01	15.66	4.24	4.09	3.78	3.98	4.18	4.19	4.43
5460	19.01	16.78	15.76	18.14	16.04	16.91	16.55	4.29	4.14	3.81	4.03	4.20	4.20	4.41
5500	19.09	16.86	15.84	18.22	16.12	16.99	16.63	4.29	4.14	3.81	4.03	4.2	4.2	4.41

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-53. Juvenile salmonid passage performance at Piazza Flashboard Dam

Model	Depth (ft)							Velocity (ft/s)						
Flow (cfs)	Channel 1	Channel 2	Channel 3	Riprap 1	Riprap 2	Riprap 3	Dam	Channel 1	Channel 2	Channel 3	Riprap 1	Riprap 2	Riprap 3	Dam
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	0.46	0.5	0.29	0.55	0.11	0.74	0.11	0.33	0.25	2.17	2.97	0.72	0.17	0.63
5	0.63	0.6	0.44	0.79	0.18	0.83	0.2	0.48	0.42	1.89	3.57	0.92	0.35	0.81
10	0.9	0.7	0.51	1.06	0.27	0.93	0.3	0.57	0.58	1.94	3.75	1.05	0.56	1.02
15	1.18	0.79	0.54	1.22	0.34	1	0.38	0.59	0.69	2.13	3.95	1.16	0.72	1.16
20	1.46	0.87	0.58	1.42	0.4	1.06	0.44	0.6	0.77	2.14	3.14	1.27	0.85	1.27
30	2.01	1.02	0.62	1.54	0.49	1.19	0.57	0.6	0.87	2.49	3.13	1.47	1.04	1.42
31	2.07	1.03	0.63	1.55	0.50	1.20	0.58	0.60	0.88	2.50	3.15	1.49	1.06	1.43
40	2.57	1.14	0.67	1.61	0.56	1.28	0.67	0.58	0.98	2.61	3.28	1.67	1.22	1.57
50	2.64	1.25	0.7	1.67	0.63	1.37	0.77	0.7	1.06	2.8	3.49	1.83	1.35	1.67
75	2.83	1.48	0.84	1.8	0.77	1.57	0.98	0.96	1.24	2.72	3.81	2.18	1.63	1.89
100	3.01	1.68	0.99	1.9	0.89	1.74	1.16	1.18	1.38	2.59	4.13	2.47	1.84	2.05
150	3.38	2.03	1.27	2.27	0.96	2.04	1.48	1.53	1.61	2.51	3.55	3.39	2.16	2.33
170	3.55	2.15	1.37	2.47	1.00	2.14	1.59	1.62	1.69	2.51	3.32	3.66	2.26	2.41
200	3.8	2.32	1.53	2.76	1.06	2.3	1.76	1.76	1.8	2.51	2.97	4.06	2.42	2.54
300	4.75	2.83	1.99	3.76	1.76	2.77	2.26	1.96	2.1	2.6	2.44	3.54	2.8	2.89
400	5.61	3.38	2.48	4.63	2.57	3.33	2.83	2.06	2.25	2.61	2.28	3.17	2.89	3.02
500	6.26	3.98	3.01	5.29	3.22	3.97	3.46	2.18	2.3	2.55	2.31	3.15	2.86	3.04
600	6.83	4.52	3.52	5.87	3.78	4.53	4.03	2.28	2.37	2.53	2.36	3.2	2.87	3.10
800	7.81	5.49	4.46	6.86	4.76	5.53	5.04	2.47	2.49	2.55	2.48	3.37	2.93	3.27
1000	8.63	6.34	5.29	7.69	5.58	6.4	5.91	2.63	2.61	2.61	2.62	3.59	3.03	3.47
1248	9.45	7.19	6.14	8.52	6.40	7.25	6.78	2.81	2.76	2.72	2.79	3.86	3.20	3.72
1500	10.28	8.06	7	9.36	7.23	8.12	7.66	3	2.92	2.83	2.96	4.14	3.37	3.97
2000	11.71	9.5	8.44	10.8	8.7	9.57	9.13	3.29	3.18	3.04	3.21	3.59	3.53	4.11
2500	12.97	10.77	9.71	12.07	9.97	10.84	10.42	3.52	3.4	3.22	3.4	3.73	3.73	4.20
3000	14.15	11.96	10.91	13.25	11.16	12.04	11.64	3.7	3.57	3.36	3.55	3.84	3.86	4.26
3500	15.21	13.01	11.97	14.32	12.23	13.1	12.72	3.87	3.74	3.5	3.69	3.95	3.99	4.34
4000	16.18	13.99	12.95	15.3	13.2	14.09	13.71	4.03	3.89	3.63	3.82	4.06	4.1	4.40
4500	17.13	14.93	13.9	16.26	14.16	15.04	14.68	4.16	4.01	3.73	3.92	4.14	4.17	4.43
5000	18.12	15.9	14.87	17.25	15.16	16.01	15.66	4.24	4.09	3.78	3.98	4.18	4.19	4.43
5500	19.09	16.86	15.84	18.22	16.12	16.99	16.63	4.29	4.14	3.81	4.03	4.2	4.2	4.41

indicates that depth criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-54. Adult Chinook passage performance at Fine Road Bridge

Model	Depth (ft)		Velocity (ft/s)	
Flow (cfs)	Channel 1	Channel 2	Channel 1	Channel 2
2	0.28	5.43	0.27	0.02
5	0.42	5.57	0.38	0.04
10	0.58	5.73	0.5	0.08
15	0.71	5.86	0.58	0.12
20	0.83	5.98	0.63	0.15
28	1.00	6.15	0.68	0.21
30	1.04	6.19	0.69	0.22
40	1.21	6.36	0.73	0.28
50	1.34	6.5	0.78	0.34
75	1.59	6.75	0.9	0.49
100	1.8	6.96	1	0.63
150	1.89	7.07	1.4	0.92
200	2.15	7.33	1.56	1.18
300	2.61	7.8	1.81	1.62
400	3.02	8.22	2.01	2.02
500	3.4	8.6	2.17	2.38
600	3.74	8.94	2.32	2.71
800	4.38	9.58	2.56	3.29
1000	4.97	10.16	2.75	3.76
1500	6.39	11.56	3.07	4.56
1590	6.61	11.78	3.11	4.65
2000	7.63	12.79	3.3	5.08
2500	8.75	13.89	3.48	5.44
3000	9.77	14.9	3.64	5.71
3500	10.71	15.83	3.78	5.92
3750	11.16	16.27	3.84	6.00
4000	11.6	16.71	3.89	6.08
4500	12.44	17.55	4	6.22
5000	13.2	18.3	4.11	6.36
5500	13.92	19.02	4.22	6.48

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-55. Adult *O. mykiss* passage performance at Fine Road Bridge

Model	Depth (ft)		Velocity (ft/s)	
Flow (cfs)	Channel 1	Channel 2	Channel 1	Channel 2
2	0.28	5.43	0.27	0.02
5	0.42	5.57	0.38	0.04
10	0.58	5.73	0.5	0.08
15	0.71	5.86	0.58	0.12
19	0.81	5.96	0.62	0.14
20	0.83	5.98	0.63	0.15
28	1.00	6.15	0.68	0.21
30	1.04	6.19	0.69	0.22
40	1.21	6.36	0.73	0.28
50	1.34	6.5	0.78	0.34
75	1.59	6.75	0.9	0.49
100	1.8	6.96	1	0.63
150	1.89	7.07	1.4	0.92
200	2.15	7.33	1.56	1.18
300	2.61	7.8	1.81	1.62
400	3.02	8.22	2.01	2.02
500	3.4	8.6	2.17	2.38
600	3.74	8.94	2.32	2.71
800	4.38	9.58	2.56	3.29
1000	4.97	10.16	2.75	3.76
1500	6.39	11.56	3.07	4.56
2000	7.63	12.79	3.3	5.08
2500	8.75	13.89	3.48	5.44
3000	9.77	14.9	3.64	5.71
3500	10.71	15.83	3.78	5.92
3750	11.16	16.27	3.84	6.00
4000	11.6	16.71	3.89	6.08
4500	12.44	17.55	4	6.22
5000	13.2	18.3	4.11	6.36
5460	13.86	18.96	4.21	6.47
5500	13.92	19.02	4.22	6.48

indicates that depth criteria are met at the section
indicates that velocity criteria are met at the section
flows inside the box allow unimpaired passage for the species/lifestage
1500 grey text indicates the flow is outside the required passage flow range
3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O. mykiss*

Table 5-56. Juvenile salmonid passage performance at Fine Road Bridge

Model Flow (cfs)	Depth (ft)		Velocity (ft/s)	
	Channel 1	Channel 2	Channel 1	Channel 2
1	N/A	N/A	N/A	N/A
2	0.28	5.43	0.27	0.02
5	0.42	5.57	0.38	0.04
7.5	0.50	5.65	0.44	0.06
10	0.58	5.73	0.5	0.08
15	0.71	5.86	0.58	0.12
19	0.81	5.96	0.62	0.14
20	0.83	5.98	0.63	0.15
30	1.04	6.19	0.69	0.22
40	1.21	6.36	0.73	0.28
50	1.34	6.5	0.78	0.34
75	1.59	6.75	0.9	0.49
100	1.8	6.96	1	0.63
150	1.89	7.07	1.4	0.92
200	2.15	7.33	1.56	1.18
300	2.61	7.8	1.81	1.62
400	3.02	8.22	2.01	2.02
500	3.4	8.6	2.17	2.38
600	3.74	8.94	2.32	2.71
800	4.38	9.58	2.56	3.29
1000	4.97	10.16	2.75	3.76
1248	5.67	10.85	2.91	4.16
1500	6.39	11.56	3.07	4.56
2000	7.63	12.79	3.3	5.08
2500	8.75	13.89	3.48	5.44
3000	9.77	14.9	3.64	5.71
3500	10.71	15.83	3.78	5.92
3750	11.16	16.27	3.84	6.00
4000	11.6	16.71	3.89	6.08
4500	12.44	17.55	4	6.22
5000	13.2	18.3	4.11	6.36
5500	13.92	19.02	4.22	6.48

indicates that depth criteria are met at the section

flows inside the box allow unimpaired passage for the species/lifestage

1500 grey text indicates the flow is outside the required passage flow range

3 bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-57. Adult Chinook passage performance at Gotelli Low Flow Road Crossing

	Depth (ft)			Velocity (ft/s)		
Model Flow (cfs)	Riprap	Culvert	Crossing	Riprap	Culvert	Crossing
1	0.27	2.00		1.50	0.16	
2.5	0.47	2.24		2.12	0.35	
3	0.52	2.29		2.15	0.40	
5	0.74	2.51		2.28	0.60	
8	0.86	2.66		2.66	0.84	
10	0.98	2.80		2.94	1.07	
15	1.18	3.03		3.40	1.47	
20	1.38	3.24		3.69	1.83	
25	1.60	3.45		3.86	2.17	
30	1.82	3.67		3.95	2.49	
34	2.00	3.83		4.00	2.74	
35	2.05	3.87		4.01	2.81	
40	2.27	4.00		4.06	3.18	
50	2.70	4.00		4.17	3.98	
60	3.10	4.00	0.00	4.28	4.77	0.00
70	3.46	4.00	0.08	4.44	4.84	0.52
80	3.80	4.00	0.46	4.57	4.57	1.44
97	4.24	4.00	0.70	2.52	4.05	1.83
100	4.32	4.00	1.02	2.16	3.96	2.23
120	4.79	4.00	1.28	1.97	3.17	2.49
140	5.17	4.00	1.49	1.79	2.40	2.68
160	5.49	4.00	1.72	1.65	1.81	2.67
180	5.77	4.00	1.98	1.55	1.61	2.49
200	6.00	4.00	2.20	1.50	1.48	2.38
250	6.48	4.00	2.67	1.44	1.39	2.24
300	6.84	4.00	3.02	1.44	1.42	2.21
350	7.14	4.00	3.33	1.45	1.09	2.23
400	7.40	4.00	3.60	1.48	1.32	2.22
450	7.64	4.00	3.83	1.52	1.41	2.23
500	7.84	4.00	4.05	1.56	0.70	2.29

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-58. Adult *O.mykiss* passage performance at Gotelli Low Flow Road Crossing

	Depth (ft)			Velocity (ft/s)		
Model Flow (cfs)	Riprap	Culvert	Crossing	Riprap	Culvert	Crossing
1	0.27	2.00		1.50	0.16	
2.5	0.47	2.24		2.12	0.35	
3	0.52	2.29		2.15	0.40	
5	0.74	2.51		2.28	0.60	
8	0.86	2.66		2.66	0.84	
10	0.98	2.80		2.94	1.07	
15	1.18	3.03		3.40	1.47	
20	1.38	3.24		3.69	1.83	
25	1.60	3.45		3.86	2.17	
30	1.82	3.67		3.95	2.49	
34	2.00	3.83		4.00	2.74	
35	2.05	3.87		4.01	2.81	
40	2.27	4.00		4.06	3.18	
50	2.70	4.00		4.17	3.98	
60	3.10	4.00	0.08	4.28	4.77	0.52
70	3.46	4.00	0.46	4.44	4.84	1.44
80	3.80	4.00	0.70	4.57	4.57	1.83
100	4.32	4.00	1.02	2.16	3.96	2.23
120	4.79	4.00	1.28	1.97	3.17	2.49
140	5.17	4.00	1.49	1.79	2.40	2.68
160	5.49	4.00	1.72	1.65	1.81	2.67
166	5.57	4.00	1.80	1.62	1.75	2.62
180	5.77	4.00	1.98	1.55	1.61	2.49
200	6.00	4.00	2.20	1.50	1.48	2.38
250	6.48	4.00	2.67	1.44	1.39	2.24
300	6.84	4.00	3.02	1.44	1.42	2.21
350	7.14	4.00	3.33	1.45	1.09	2.23
400	7.40	4.00	3.60	1.48	1.32	2.22
450	7.64	4.00	3.83	1.52	1.41	2.23
500	7.84	4.00	4.05	1.56	0.70	2.29

(cyan)	indicates that depth criteria are met at the section
(green)	indicates that velocity criteria are met at the section
(red box)	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Table 5-59. Juvenile salmonid passage performance at Gotelli Low Flow Road Crossing

Model Flow (cfs)	Depth (ft)			Velocity (ft/s)		
	Riprap	Culvert	Weir	Riprap	Culvert	Weir
1	0.27	2.00		1.50	0.16	
2.5	0.47	2.24		2.12	0.35	
5	0.74	2.51		2.28	0.60	
8	0.86	2.66		2.66	0.84	
10	0.98	2.80		2.94	1.07	
10.5	1.00	2.82		2.99	1.11	
15	1.18	3.03		3.40	1.47	
20	1.38	3.24		3.69	1.83	
25	1.60	3.45		3.86	2.17	
30	1.82	3.67		3.95	2.49	
35	2.05	3.87		4.01	2.81	
38	2.18	3.95		4.04	3.03	
40	2.27	4.00		4.06	3.18	
50	2.70	4.00		4.17	3.98	
60	3.10	4.00	0.08	4.28	4.77	0.52
70	3.46	4.00	0.46	4.44	4.84	1.44
80	3.80	4.00	0.70	4.57	4.57	1.83
100	4.32	4.00	1.02	2.16	3.96	2.23
120	4.79	4.00	1.28	1.97	3.17	2.49
140	5.17	4.00	1.49	1.79	2.40	2.68
160	5.49	4.00	1.72	1.65	1.81	2.67
180	5.77	4.00	1.98	1.55	1.61	2.49
200	6.00	4.00	2.20	1.50	1.48	2.38
250	6.48	4.00	2.67	1.44	1.39	2.24
300	6.84	4.00	3.02	1.44	1.42	2.21
350	7.14	4.00	3.33	1.45	1.09	2.23
400	7.40	4.00	3.60	1.48	1.32	2.22
450	7.64	4.00	3.83	1.52	1.41	2.23
500	7.84	4.00	4.05	1.56	0.70	2.29

	indicates that depth criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of juvenile salmonids

Table 5-60. Adult Chinook passage performance at McAllen Road Bridge

Model Flow	Depth (ft)				Velocity (ft/s)			
(cfs)	Riprap 2	Riprap 1	Bridge DS	Bridge US	Riprap 2	Riprap 1	Bridge DS	Bridge US
1	0.38	0.29	0.40	0.52	0.63	0.92	0.57	0.47
2.5	0.61	0.44	0.57	0.74	0.87	1.23	0.86	0.64
3	0.68	0.48	0.61	0.79	0.89	1.27	0.91	0.67
5	0.95	0.66	0.78	0.98	0.98	1.42	1.10	0.80
8	1.21	0.86	0.96	1.16	1.04	1.45	1.23	0.91
10	1.46	1.04	1.13	1.32	1.06	1.45	1.29	0.97
15	1.69	1.27	1.35	1.56	1.29	1.62	1.47	1.09
20	1.80	1.41	1.50	1.73	1.55	1.84	1.67	1.20
25	1.94	1.55	1.65	1.90	1.74	1.99	1.81	1.30
30	2.07	1.68	1.78	2.03	1.89	2.11	1.93	1.39
35	2.24	1.84	1.93	2.18	1.95	2.14	1.99	1.44
37	2.32	1.91	2.00	2.25	1.97	2.15	2.01	1.46
40	2.41	1.99	2.08	2.33	2.00	2.17	2.03	1.48
40.3	2.42	2.00	2.09	2.34	2.00	2.17	2.03	1.48
50	2.74	2.29	2.37	2.60	2.07	2.18	2.07	1.54
60	3.05	2.59	2.65	2.86	2.11	2.17	2.08	1.57
70	3.35	2.87	2.92	3.11	2.13	2.14	2.08	1.57
80	3.63	3.14	3.19	3.35	2.15	2.12	2.06	1.56
97	4.06	3.57	3.62	3.66	2.19	2.04	2.00	1.60
100	4.14	3.65	3.69	3.72	2.20	2.02	1.99	1.61
120	4.60	4.10	4.13	4.15	2.23	1.93	1.94	1.60
140	5.02	4.52	4.55	4.54	2.24	1.88	1.91	1.58
160	5.41	4.90	4.92	4.91	2.21	1.85	1.89	1.57
180	5.73	5.22	5.24	5.22	2.20	1.86	1.90	1.59
200	5.96	5.45	5.47	5.44	2.23	1.91	1.95	1.65
250	6.40	5.89	5.90	5.88	2.35	2.07	2.13	1.81
300	6.76	6.24	6.25	6.24	2.48	2.21	2.28	1.97
350	7.06	6.55	6.56	6.55	2.61	2.34	2.42	2.12
400	7.33	6.82	6.83	6.83	2.73	2.46	2.55	2.27
450	7.57	7.06	7.07	7.08	2.84	2.58	2.68	2.40
500	7.80	7.29	7.30	7.29	2.95	2.68	2.79	2.55

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-61. Adult *O. mykiss* passage performance at McAllen Road Bridge

Model Flow (cfs)	Depth (ft)				Velocity (ft/s)			
	Riprap 2	Riprap 1	Bridge DS	Bridge US	Riprap 2	Riprap 1	Bridge DS	Bridge US
1	0.38	0.29	0.40	0.52	0.63	0.92	0.57	0.47
2.5	0.61	0.44	0.57	0.74	0.87	1.23	0.86	0.64
3	0.68	0.48	0.61	0.79	0.89	1.27	0.91	0.67
5	0.95	0.66	0.78	0.98	0.98	1.42	1.10	0.80
8	1.21	0.86	0.96	1.16	1.04	1.45	1.23	0.91
8.1	1.27	0.90	1.00	1.20	1.04	1.45	1.24	0.92
10	1.46	1.04	1.13	1.32	1.06	1.45	1.29	0.97
15	1.69	1.27	1.35	1.56	1.29	1.62	1.47	1.09
20	1.80	1.41	1.50	1.73	1.55	1.84	1.67	1.20
25	1.94	1.55	1.65	1.90	1.74	1.99	1.81	1.30
30	2.07	1.68	1.78	2.03	1.89	2.11	1.93	1.39
35	2.24	1.84	1.93	2.18	1.95	2.14	1.99	1.44
40	2.41	1.99	2.08	2.33	2.00	2.17	2.03	1.48
40.3	2.42	2.00	2.09	2.34	2.00	2.17	2.03	1.48
50	2.74	2.29	2.37	2.60	2.07	2.18	2.07	1.54
60	3.05	2.59	2.65	2.86	2.11	2.17	2.08	1.57
70	3.35	2.87	2.92	3.11	2.13	2.14	2.08	1.57
80	3.63	3.14	3.19	3.35	2.15	2.12	2.06	1.56
100	4.14	3.65	3.69	3.72	2.20	2.02	1.99	1.61
120	4.60	4.10	4.13	4.15	2.23	1.93	1.94	1.60
140	5.02	4.52	4.55	4.54	2.24	1.88	1.91	1.58
160	5.41	4.90	4.92	4.91	2.21	1.85	1.89	1.57
166	5.51	5.00	5.02	5.00	2.21	1.85	1.89	1.58
180	5.73	5.22	5.24	5.22	2.20	1.86	1.90	1.59
200	5.96	5.45	5.47	5.44	2.23	1.91	1.95	1.65
250	6.40	5.89	5.90	5.88	2.35	2.07	2.13	1.81
300	6.76	6.24	6.25	6.24	2.48	2.21	2.28	1.97
350	7.06	6.55	6.56	6.55	2.61	2.34	2.42	2.12
400	7.33	6.82	6.83	6.83	2.73	2.46	2.55	2.27
450	7.57	7.06	7.07	7.08	2.84	2.58	2.68	2.40
500	7.80	7.29	7.30	7.29	2.95	2.68	2.79	2.55

(cyan)	indicates that depth criteria are met at the section
(green)	indicates that velocity criteria are met at the section
(red box)	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Table 5-62. Juvenile salmonid passage performance at McAllen Road Bridge

Model Flow (cfs)	Depth (ft)				Velocity (ft/s)			
	Riprap 2	Riprap 1	Bridge DS	Bridge US	Riprap 2	Riprap 1	Bridge DS	Bridge US
1	0.38	0.29	0.40	0.52	0.63	0.92	0.57	0.47
2.5	0.61	0.44	0.57	0.74	0.87	1.23	0.86	0.64
5	0.95	0.66	0.78	0.98	0.98	1.42	1.10	0.80
7.5	1.21	0.86	0.96	1.16	1.04	1.45	1.23	0.91
9	1.40	1.00	1.09	1.28	1.06	1.45	1.28	0.96
10	1.46	1.04	1.13	1.32	1.06	1.45	1.29	0.97
15	1.69	1.27	1.35	1.56	1.29	1.62	1.47	1.09
20	1.80	1.41	1.50	1.73	1.55	1.84	1.67	1.20
25	1.94	1.55	1.65	1.90	1.74	1.99	1.81	1.30
30	2.07	1.68	1.78	2.03	1.89	2.11	1.93	1.39
35	2.24	1.84	1.93	2.18	1.95	2.14	1.99	1.44
38	2.34	1.93	2.02	2.27	1.98	2.16	2.01	1.46
40	2.41	1.99	2.08	2.33	2.00	2.17	2.03	1.48
50	2.74	2.29	2.37	2.60	2.07	2.18	2.07	1.54
60	3.05	2.59	2.65	2.86	2.11	2.17	2.08	1.57
70	3.35	2.87	2.92	3.11	2.13	2.14	2.08	1.57
80	3.63	3.14	3.19	3.35	2.15	2.12	2.06	1.56
100	4.14	3.65	3.69	3.72	2.20	2.02	1.99	1.61
120	4.60	4.10	4.13	4.15	2.23	1.93	1.94	1.60
140	5.02	4.52	4.55	4.54	2.24	1.88	1.91	1.58
160	5.41	4.90	4.92	4.91	2.21	1.85	1.89	1.57
180	5.73	5.22	5.24	5.22	2.20	1.86	1.90	1.59
200	5.96	5.45	5.47	5.44	2.23	1.91	1.95	1.65
250	6.40	5.89	5.90	5.88	2.35	2.07	2.13	1.81
300	6.76	6.24	6.25	6.24	2.48	2.21	2.28	1.97
350	7.06	6.55	6.56	6.55	2.61	2.34	2.42	2.12
400	7.33	6.82	6.83	6.83	2.73	2.46	2.55	2.27
450	7.57	7.06	7.07	7.08	2.84	2.58	2.68	2.40
500	7.80	7.29	7.30	7.29	2.95	2.68	2.79	2.55

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of period of juvenile salmonid

Table 5-63. Adult Chinook passage performance at McAllen Flashboard Dam

Model Flow	Depth (ft)				Velocity (ft/s)			
(cfs)	Riprap	Bridge	apron	dam	Riprap	Bridge	apron	dam
1	0.29	0.40	0.09	0.10	0.92	0.57	0.71	0.71
2.5	0.44	0.57	0.16	0.17	1.23	0.86	0.94	0.94
3	0.48	0.61	0.18	0.19	1.27	0.91	0.99	0.98
5	0.66	0.78	0.24	0.25	1.42	1.10	1.17	1.17
8	0.86	0.96	0.31	0.32	1.45	1.23	1.34	1.34
10	1.04	1.13	0.38	0.39	1.45	1.29	1.42	1.42
15	1.27	1.35	0.59	0.59	1.62	1.47	1.33	1.33
20	1.41	1.50	0.78	0.78	1.84	1.67	1.31	1.31
25	1.55	1.65	0.94	0.95	1.99	1.81	1.32	1.32
30	1.68	1.78	1.10	1.10	2.11	1.93	1.33	1.33
35	1.84	1.93	1.26	1.26	2.14	1.99	1.33	1.33
40	1.99	2.08	1.40	1.40	2.17	2.03	1.35	1.35
40.3	2.00	2.09	1.41	1.41	2.17	2.03	1.35	1.35
50	2.29	2.37	1.66	1.67	2.18	2.07	1.38	1.38
60	2.59	2.65	1.91	1.92	2.17	2.08	1.40	1.40
70	2.87	2.92	2.15	2.16	2.14	2.08	1.42	1.42
80	3.14	3.19	2.38	2.39	2.12	2.06	1.44	1.44
97	3.57	3.62	2.69	2.70	2.04	2.00	1.49	1.49
100	3.65	3.69	2.75	2.76	2.02	1.99	1.50	1.50
120	4.10	4.13	3.16	3.17	1.93	1.94	1.51	1.51
140	4.52	4.55	3.56	3.57	1.88	1.91	1.52	1.52
160	4.90	4.92	3.91	3.93	1.85	1.89	1.53	1.53
180	5.22	5.24	4.23	4.25	1.86	1.90	1.55	1.55
200	5.45	5.47	4.47	4.48	1.91	1.95	1.60	1.60
250	5.89	5.90	4.93	4.95	2.07	2.13	1.75	1.75
300	6.24	6.25	5.30	5.31	2.21	2.28	1.90	1.90
350	6.55	6.56	5.65	5.67	2.34	2.42	2.03	2.03
400	6.82	6.83	5.97	5.99	2.46	2.55	2.15	2.15
450	7.06	7.07	6.25	6.28	2.58	2.68	2.27	2.27
500	7.29	7.30	6.48	6.50	2.68	2.79	2.40	2.40

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult Chinook

Table 5-64. Adult *O. mykiss* passage performance at McAllen Flashboard Dam

Model Flow (cfs)	Depth (ft)				Velocity (ft/s)			
	Riprap	Bridge	apron	dam	Riprap	Bridge	apron	dam
1	0.29	0.40	0.09	0.10	0.92	0.57	0.71	0.71
2.5	0.44	0.57	0.16	0.17	1.23	0.86	0.94	0.94
3	0.48	0.61	0.18	0.19	1.27	0.91	0.99	0.98
5	0.66	0.78	0.24	0.25	1.42	1.10	1.17	1.17
8	0.86	0.96	0.31	0.32	1.45	1.23	1.34	1.34
10	1.04	1.13	0.38	0.39	1.45	1.29	1.42	1.42
15	1.27	1.35	0.59	0.59	1.62	1.47	1.33	1.33
20	1.41	1.50	0.78	0.78	1.84	1.67	1.31	1.31
25	1.55	1.65	0.94	0.95	1.99	1.81	1.32	1.32
30	1.68	1.78	1.10	1.10	2.11	1.93	1.33	1.33
35	1.84	1.93	1.26	1.26	2.14	1.99	1.33	1.33
40	1.99	2.08	1.40	1.40	2.17	2.03	1.35	1.35
40.3	2.00	2.09	1.41	1.41	2.17	2.03	1.35	1.35
50	2.29	2.37	1.66	1.67	2.18	2.07	1.38	1.38
60	2.59	2.65	1.91	1.92	2.17	2.08	1.40	1.40
67	2.79	2.84	2.08	2.09	2.15	2.08	1.41	1.42
70	2.87	2.92	2.15	2.16	2.14	2.08	1.42	1.42
80	3.14	3.19	2.38	2.39	2.12	2.06	1.44	1.44
100	3.65	3.69	2.75	2.76	2.02	1.99	1.50	1.50
120	4.10	4.13	3.16	3.17	1.93	1.94	1.51	1.51
140	4.52	4.55	3.56	3.57	1.88	1.91	1.52	1.52
160	4.90	4.92	3.91	3.93	1.85	1.89	1.53	1.53
166	5.00	5.02	4.01	4.03	1.85	1.89	1.54	1.54
180	5.22	5.24	4.23	4.25	1.86	1.90	1.55	1.55
200	5.45	5.47	4.47	4.48	1.91	1.95	1.60	1.60
250	5.89	5.90	4.93	4.95	2.07	2.13	1.75	1.75
300	6.24	6.25	5.30	5.31	2.21	2.28	1.90	1.90
350	6.55	6.56	5.65	5.67	2.34	2.42	2.03	2.03
400	6.82	6.83	5.97	5.99	2.46	2.55	2.15	2.15
450	7.06	7.07	6.25	6.28	2.58	2.68	2.27	2.27
500	7.29	7.30	6.48	6.50	2.68	2.79	2.40	2.40

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Table 5-65. Juvenile salmonid passage performance at McAllen Flashboard Dam

Model Flow (cfs)	Depth (ft)				Velocity (ft/s)			
	Riprap	Bridge	apron	dam	Riprap	Bridge	apron	dam
1	0.29	0.40	0.09	0.10	0.92	0.57	0.71	0.71
2.5	0.44	0.57	0.16	0.17	1.23	0.86	0.94	0.94
5	0.66	0.78	0.24	0.25	1.42	1.10	1.17	1.17
8	0.86	0.96	0.31	0.32	1.45	1.23	1.34	1.34
10	1.04	1.13	0.38	0.39	1.45	1.29	1.42	1.42
13	1.17	1.26	0.50	0.50	1.55	1.39	1.37	1.37
15	1.27	1.35	0.59	0.59	1.62	1.47	1.33	1.33
20	1.41	1.50	0.78	0.78	1.84	1.67	1.31	1.31
25	1.55	1.65	0.94	0.95	1.99	1.81	1.32	1.32
30	1.68	1.78	1.10	1.10	2.11	1.93	1.33	1.33
35	1.84	1.93	1.26	1.26	2.14	1.99	1.33	1.33
38	1.93	2.02	1.34	1.34	2.16	2.01	1.34	1.34
40	1.99	2.08	1.40	1.40	2.17	2.03	1.35	1.35
40.3	2.00	2.09	1.41	1.41	2.17	2.03	1.35	1.35
50	2.29	2.37	1.66	1.67	2.18	2.07	1.38	1.38
60	2.59	2.65	1.91	1.92	2.17	2.08	1.40	1.40
70	2.87	2.92	2.15	2.16	2.14	2.08	1.42	1.42
80	3.14	3.19	2.38	2.39	2.12	2.06	1.44	1.44
100	3.65	3.69	2.75	2.76	2.02	1.99	1.50	1.50
120	4.10	4.13	3.16	3.17	1.93	1.94	1.51	1.51
140	4.52	4.55	3.56	3.57	1.88	1.91	1.52	1.52
160	4.90	4.92	3.91	3.93	1.85	1.89	1.53	1.53
180	5.22	5.24	4.23	4.25	1.86	1.90	1.55	1.55
200	5.45	5.47	4.47	4.48	1.91	1.95	1.60	1.60
250	5.89	5.90	4.93	4.95	2.07	2.13	1.75	1.75
300	6.24	6.25	5.30	5.31	2.21	2.28	1.90	1.90
350	6.55	6.56	5.65	5.67	2.34	2.42	2.03	2.03
400	6.82	6.83	5.97	5.99	2.46	2.55	2.15	2.15
450	7.06	7.07	6.25	6.28	2.58	2.68	2.27	2.27
500	7.29	7.30	6.48	6.50	2.68	2.79	2.40	2.40

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range

Table 5-66. Adult Chinook passage performance at Cherryland Flashboard Dam

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	riprap 4	riprap 3	riprap 2	riprap 1	apron	dam	riprap 4	riprap 3	riprap 2	riprap 1	apron	dam
1	0.22	0.64	0.42	1.30	0.12	0.20	0.53	2.27	1.82	0.15	1.63	1.02
3	0.37	1.15	0.73	1.62	0.19	0.30	0.65	1.73	1.95	0.26	2.20	1.37
3	0.41	1.17	0.77	1.68	0.21	0.32	0.67	1.82	2.10	0.29	2.32	1.46
5	0.57	1.24	0.94	1.90	0.28	0.40	0.74	2.17	2.72	0.42	2.80	1.83
8	0.74	1.32	1.11	2.13	0.36	0.49	0.78	2.44	3.29	0.53	3.19	2.11
10	0.89	1.38	1.26	2.33	0.43	0.56	0.81	2.64	3.77	0.63	3.45	2.38
15	1.08	1.49	1.54	2.57	0.54	0.68	0.95	2.97	3.49	0.83	3.92	2.77
18	1.15	1.54	1.59	2.64	0.61	0.73	1.02	3.10	3.69	0.93	4.00	2.93
20	1.22	1.58	1.63	2.71	0.67	0.78	1.08	3.22	3.88	1.03	4.08	3.08
22	1.28	1.61	1.66	2.76	0.72	0.81	1.11	3.29	4.00	1.09	4.11	3.19
25	1.37	1.66	1.72	2.84	0.80	0.87	1.17	3.40	4.20	1.20	4.16	3.37
26	1.39	1.67	1.73	2.82	0.80	0.88	1.17	3.41	4.00	1.24	4.22	3.40
30	1.56	1.75	1.78	2.68	0.84	0.95	1.19	3.47	2.42	1.56	4.70	3.61
34	1.70	1.81	1.78	2.70	0.90	1.01	1.20	3.48	2.71	1.73	4.84	3.75
35	1.75	1.83	1.78	2.71	0.92	1.03	1.21	3.49	2.82	1.80	4.89	3.81
38	1.85	1.88	1.78	2.73	0.97	1.06	1.22	3.49	3.05	1.93	5.00	3.92
40	1.93	1.92	1.78	2.74	1.00	1.09	1.23	3.49	3.22	2.02	5.08	4.00
50	2.28	2.11	1.81	2.84	1.18	1.22	1.26	3.36	3.85	2.40	5.13	4.33
60	2.61	2.31	1.97	2.87	1.38	1.33	1.29	3.14	3.08	2.83	5.03	4.63
62	2.67	2.35	2.00	2.90	1.42	1.35	1.29	3.09	3.08	2.88	5.01	4.67
70	2.92	2.51	2.12	3.00	1.57	1.45	1.30	2.90	3.07	3.08	4.95	4.81
80	3.23	2.74	2.29	3.15	1.74	1.57	1.30	2.63	3.00	3.24	4.94	4.94
97	3.71	3.16	2.62	3.46	2.00	1.76	1.27	2.29	2.80	3.29	4.92	5.13
100	3.80	3.23	2.68	3.52	2.05	1.79	1.27	2.23	2.77	3.30	4.92	5.16
120	4.32	3.72	3.12	3.94	2.33	2.01	1.26	1.99	2.55	3.14	4.93	5.25
140	4.80	4.18	3.54	4.36	2.60	2.22	1.26	1.86	2.39	2.93	4.88	5.29
160	5.23	4.60	3.95	4.77	2.89	2.50	1.28	1.78	2.28	2.76	4.73	5.05
180	5.63	5.00	4.34	5.16	3.21	2.82	1.29	1.74	2.20	2.63	4.49	4.72
200	6.02	5.38	4.71	5.53	3.56	3.15	1.31	1.71	2.15	2.53	4.19	4.39
250	6.88	6.25	5.57	6.39	4.37	3.93	1.35	1.68	2.06	2.36	3.65	3.80
300	7.60	6.96	6.28	7.10	5.08	4.65	1.40	1.70	2.05	2.29	3.33	3.43
350	8.19	7.55	6.86	7.69	5.66	5.25	1.47	1.74	2.08	2.29	3.19	3.26
400	8.71	8.07	7.38	8.21	6.18	5.76	1.54	1.80	2.11	2.30	3.11	3.18
450	9.16	8.52	7.84	8.66	6.64	6.23	1.61	1.86	2.16	2.33	3.07	3.13
500	9.57	8.93	8.25	9.07	7.06	6.65	1.68	1.91	2.20	2.36	3.07	3.11

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Table 5-67. Adult *O. mykiss* passage performance at Cherryland Flashboard Dam

Model Flow (cfs)	Depth (ft)						Velocity (ft/s)					
	riprap 4	riprap 3	riprap 2	riprap 1	apron	dam	riprap 4	riprap 3	riprap 2	riprap 1	apron	dam
1	0.22	0.64	0.42	1.30	0.12	0.20	0.53	2.27	1.82	0.15	1.63	1.02
3	0.37	1.15	0.73	1.62	0.19	0.30	0.65	1.73	1.95	0.26	2.20	1.37
3	0.41	1.17	0.77	1.68	0.21	0.32	0.67	1.82	2.10	0.29	2.32	1.46
5	0.57	1.24	0.94	1.90	0.28	0.40	0.74	2.17	2.72	0.42	2.80	1.83
8	0.74	1.32	1.11	2.13	0.36	0.49	0.78	2.44	3.29	0.53	3.19	2.11
10	0.89	1.38	1.26	2.33	0.43	0.56	0.81	2.64	3.77	0.63	3.45	2.38
15	1.08	1.49	1.54	2.57	0.54	0.68	0.95	2.97	3.49	0.83	3.92	2.77
18	1.15	1.54	1.59	2.64	0.61	0.73	1.02	3.10	3.69	0.93	4.00	2.93
20	1.22	1.58	1.63	2.71	0.67	0.78	1.08	3.22	3.88	1.03	4.08	3.08
22	1.28	1.61	1.66	2.76	0.72	0.81	1.11	3.29	4.00	1.09	4.11	3.19
25	1.37	1.66	1.72	2.84	0.80	0.87	1.17	3.40	4.20	1.20	4.16	3.37
26	1.39	1.67	1.73	2.82	0.80	0.88	1.17	3.41	4.00	1.24	4.22	3.40
30	1.56	1.75	1.78	2.68	0.84	0.95	1.19	3.47	2.42	1.56	4.70	3.61
33	1.68	1.80	1.78	2.70	0.89	1.00	1.20	3.48	2.67	1.71	4.82	3.73
35	1.75	1.83	1.78	2.71	0.92	1.03	1.21	3.49	2.82	1.80	4.89	3.81
38	1.85	1.88	1.78	2.73	0.97	1.06	1.22	3.49	3.05	1.93	5.00	3.92
40	1.93	1.92	1.78	2.74	1.00	1.09	1.23	3.49	3.22	2.02	5.08	4.00
50	2.28	2.11	1.81	2.84	1.18	1.22	1.26	3.36	3.85	2.40	5.13	4.33
60	2.61	2.31	1.97	2.87	1.38	1.33	1.29	3.14	3.08	2.83	5.03	4.63
62	2.67	2.35	2.00	2.90	1.42	1.35	1.29	3.09	3.08	2.88	5.01	4.67
70	2.92	2.51	2.12	3.00	1.57	1.45	1.30	2.90	3.07	3.08	4.95	4.81
80	3.23	2.74	2.29	3.15	1.74	1.57	1.30	2.63	3.00	3.24	4.94	4.94
100	3.80	3.23	2.68	3.52	2.05	1.79	1.27	2.23	2.77	3.30	4.92	5.16
120	4.32	3.72	3.12	3.94	2.33	2.01	1.26	1.99	2.55	3.14	4.93	5.25
140	4.80	4.18	3.54	4.36	2.60	2.22	1.26	1.86	2.39	2.93	4.88	5.29
160	5.23	4.60	3.95	4.77	2.89	2.50	1.28	1.78	2.28	2.76	4.73	5.05
166	5.35	4.72	4.07	4.89	2.99	2.60	1.28	1.77	2.26	2.72	4.66	4.95
180	5.63	5.00	4.34	5.16	3.21	2.82	1.29	1.74	2.20	2.63	4.49	4.72
200	6.02	5.38	4.71	5.53	3.56	3.15	1.31	1.71	2.15	2.53	4.19	4.39
250	6.88	6.25	5.57	6.39	4.37	3.93	1.35	1.68	2.06	2.36	3.65	3.80
300	7.60	6.96	6.28	7.10	5.08	4.65	1.40	1.70	2.05	2.29	3.33	3.43
350	8.19	7.55	6.86	7.69	5.66	5.25	1.47	1.74	2.08	2.29	3.19	3.26
400	8.71	8.07	7.38	8.21	6.18	5.76	1.54	1.80	2.11	2.30	3.11	3.18
450	9.16	8.52	7.84	8.66	6.64	6.23	1.61	1.86	2.16	2.33	3.07	3.13
500	9.57	8.93	8.25	9.07	7.06	6.65	1.68	1.91	2.20	2.36	3.07	3.11

	indicates that depth criteria are met at the section
	indicates that velocity criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Table 5-68. Juvenile salmonid passage performance at Cherryland Flashboard Dam

Model	Depth (ft)						Velocity (ft/s)					
Flow (cfs)	riprap 4	riprap 3	riprap 2	riprap 1	apron	dam	riprap 4	riprap 3	riprap 2	riprap 1	apron	dam
1	0.22	0.64	0.42	1.30	0.12	0.20	0.53	2.27	1.82	0.15	1.63	1.02
3	0.37	1.15	0.73	1.62	0.19	0.31	0.65	1.73	1.95	0.26	2.20	1.37
5	0.57	1.24	0.94	1.90	0.28	0.42	0.74	2.17	2.72	0.42	2.80	1.83
8	0.74	1.32	1.11	2.13	0.36	0.50	0.78	2.44	3.29	0.53	3.19	2.11
10	0.89	1.38	1.26	2.33	0.43	0.56	0.81	2.64	3.77	0.63	3.45	2.38
13	1.00	1.45	1.43	2.47	0.50	0.64	0.89	2.84	3.60	0.75	3.73	2.62
15	1.08	1.49	1.54	2.57	0.54	0.69	0.95	2.97	3.49	0.83	3.92	2.77
20	1.22	1.58	1.63	2.71	0.67	0.81	1.08	3.22	3.88	1.03	4.08	3.09
25	1.37	1.66	1.72	2.84	0.80	0.90	1.17	3.40	4.20	1.20	4.16	3.37
30	1.56	1.75	1.78	2.68	0.84	0.98	1.19	3.47	2.42	1.56	4.70	3.61
35	1.75	1.83	1.78	2.71	0.92	1.06	1.21	3.49	2.82	1.80	4.89	3.81
38	1.86	1.88	1.78	2.73	0.97	1.10	1.22	3.49	3.06	1.93	5.00	3.92
40	1.93	1.92	1.78	2.74	1.00	1.13	1.23	3.49	3.22	2.02	5.08	4.00
50	2.28	2.11	1.81	2.84	1.18	1.26	1.26	3.36	3.85	2.40	5.13	4.33
60	2.61	2.31	1.97	2.87	1.38	1.38	1.29	3.14	3.08	2.83	5.03	4.63
62	2.67	2.35	2.00	2.90	1.42	1.41	1.29	3.09	3.08	2.88	5.01	4.67
70	2.92	2.51	2.12	3.00	1.57	1.51	1.30	2.90	3.07	3.08	4.95	4.81
80	3.23	2.74	2.29	3.15	1.74	1.65	1.30	2.63	3.00	3.24	4.94	4.94
100	3.80	3.23	2.68	3.52	2.05	1.87	1.27	2.23	2.77	3.30	4.92	5.15
120	4.32	3.72	3.12	3.94	2.33	2.10	1.26	1.99	2.55	3.14	4.93	5.25
140	4.80	4.18	3.54	4.36	2.60	2.32	1.26	1.86	2.39	2.93	4.88	5.29
160	5.23	4.60	3.95	4.77	2.89	2.60	1.28	1.78	2.28	2.76	4.73	5.05
180	5.63	5.00	4.34	5.16	3.21	2.91	1.29	1.74	2.20	2.63	4.49	4.72
200	6.02	5.38	4.71	5.53	3.56	3.25	1.31	1.71	2.15	2.53	4.19	4.39
250	6.88	6.25	5.57	6.39	4.37	4.04	1.35	1.68	2.06	2.36	3.65	3.80
300	7.60	6.96	6.28	7.10	5.08	4.76	1.40	1.70	2.05	2.29	3.33	3.43
350	8.19	7.55	6.86	7.69	5.66	5.37	1.47	1.74	2.08	2.29	3.19	3.26
400	8.71	8.07	7.38	8.21	6.18	5.90	1.54	1.80	2.11	2.30	3.11	3.18
450	9.16	8.52	7.84	8.66	6.64	6.38	1.61	1.86	2.16	2.33	3.07	3.13
500	9.57	8.93	8.25	9.07	7.06	6.82	1.68	1.91	2.20	2.36	3.07	3.11

	indicates that depth criteria are met at the section
	flows inside the box allow unimpaired passage for the species/lifestage
1500	grey text indicates the flow is outside the required passage flow range
3	bold text indicates the flow is either the lower or upper exceedance passage flow for the migration period of adult *O.mykiss*

Chapter 5 Fish Passage Evaluation Results

List of Photos

Photo 5-1. Central California Traction Railroad Bridge – Side view

Photo 5-2. Budiselich Flashboard Dam – View from left bank of base with riprap downstream

Photo 5-3. Caprini Low-flow Road Crossing

Photo 5-4. Hogan Low-flow Road Crossing

Photo 5-5. Hosie Low-flow Road Crossing

Photo 5-6. Watkins Low Flow Road Crossing

Photo 5-7. Murphy Flashboard Dam

Photo 5-8. Clements Road Flashboard Dam with boards in place

Photo 5-9. Lavaggi Flashboard Dam with boards in place

Photo 5-10. Fujinaka Low-flow Road Crossing with flow

Photo 5-11. Mormon Slough Railroad Bridge – Upstream side

Photo 5-12. Piazza Flashboard Dam base at a low flow

Photo 5-13. Fine Road Bridge

Photo 5-14. Gotelli Low-flow Road Crossing

Photo 5-15. McAllen Road Bridge from the upstream side

Photo 5-16. McAllen Flashboard Dam without boards in place

Photo 5-17. Cherryland Flashboard Dam without boards in place

Chapter 6 Conclusion

None of the 17 structures modeled allowed 100% passage during the adult Chinook, *O. mykiss*, or juvenile migration periods. This implies that all 97 structures on Calaveras River, Mormon Slough, and Stockton Diverting Canal represented by the modeled structures are likely to be impassable at some point during each migration season.

Riprap was often the feature that had the greatest impact on fish passage at modeled structures. Riprap was responsible for passage problems at 10 of the 17 modeled structures, indicating that the use of riprap should be eliminated at structures and in the channel where possible. The remaining structures were limited by high velocities over the structure (two sites), shallow depth over the structures (three sites), and shallow depths in the channel (two sites).

Although bridges are typically considered a lesser problem for fish passage when compared to other types of structural barriers (NMFS 2001), bridges on the Calaveras River, Mormon Slough, and Stockton Diverting Canal may have some percentage of impairment. We modeled two bridges (McAllen Road Bridge and Fine Road Bridge) that represented bridges with scores of 3 or less in the ranking. The modeling results for both sites indicate that riprap and shallow channel depths may also limit fish passage at the other 50 bridges. The likelihood of fish passage impairment increases where concrete spread footings of bridge crossings span between the piers or when the bridge decks and piers are at a skewed angle compared to the channel alignment.

This evaluation does not prescribe one particular flow or range of flows that can be used to provide fish passage at structures in the system. The specific flow ranges under which a represented structure is impaired will differ from the modeled structure that represents that group. For example, the flows necessary to provide unimpaired passage for adult Chinook and *O. mykiss* at all the modeled structures on the Calaveras River downstream of the Headworks ranged from 26 to 67 cubic feet per second. The reader should not select 67 cfs as the minimum flow necessary to provide unimpaired fish passage at all structures in the Calaveras River downstream of the Headworks. A flow of 67 cfs does not ensure that passage will occur in the channel between structures. This is true because channel roughness may result in energy losses due to such things as accumulated sediment deposits, woody debris, riprap, or excessive instream vegetation.

Results from the evaluation can be used to prioritize design solutions for fish passage problems at structures on the Calaveras River, Mormon Slough, and Stockton Diverting Canal. Within our study reach, the six[1] flashboard dams that are most likely to cause fish passage impairment (with the boards in place) are Cherryland, Panella, Lavaggi, McClean, Prato, and Clements flashboard dams. The three structures most likely to cause fish passage impairment (other than flashboard dams with their boards in place) are Clements Road Flashboard Dam (boards removed), Bellota Weir (boards removed), and Cherryland Flashboard Dam (boards removed). However, the reader should note that the scoring does not always equate to the percentage of time when salmonids encounter unimpaired passage at a structure. For

[1] These six flashboard dams are listed because they all received a score of 9.

example, Gotelli Low-flow Road Crossing (RM 6.2) received a score of 3 and provides unimpaired passage 4%, 9%, and 48% of the time for adult Chinook, *O.mykiss*, and juvenile salmonids, respectively. In contrast, Central California Traction Railroad Bridge (RM 1.1) received a score of 5, implying that it is worse for fish passage, but it provides unimpaired passage 5%, 18%, and 46% of the time for adult Chinook, *O. mykiss*, and juvenile salmonids. Therefore, it is important that the scored structure lists be used in concert with other factors, such as location in the watershed, landowner cooperation, cost of removing or modifying the structure, etc. to determine structure redesign priorities.

To allow passage for adult and juvenile salmonids, temporary and permanent solutions for fish passage are recommended at the structures on the Calaveras River System. The third part of this report, “Calaveras River Fish Migration Barriers Assessment Report -- Selected Preliminary Designs,” will present six preliminary designs for fish passage at Cherryland and Clements flashboard dams and Gotelli Low-flow Road Crossing on the Calaveras River, Budiselich Flashboard Dam on the Stockton Diverting Canal, and Caprini and Hosie low-flow road crossings on Mormon Slough. Conceptual designs will be presented for the Calaveras Headworks on the Calaveras River and Central California Traction Railroad Crossing on the Stockton Diverting Canal. In addition, temporary and permanent generic fish passage solutions will be presented. These designs and solutions can be used as guides for developing fish passage solutions at other structures in the Calaveras River System.

Chapter 7 Glossary

Abiotic: Not alive; non-biological; for example, temperature and mixing are abiotic factors that influence the O_2 content water whereas photosynthesis and respiration are biotic factors that affect O_2 solubility.

Abutment: A structure that supports the ends of a dam or bridge.

Acre-foot (af): Unit commonly used to measure volume of water; equal to 43,560 cubic feet, or 325,861 gallons (will cover one acre one foot deep).

Aggrade: To increase channel elevation by sediment accumulation.

Alevin: The developmental life stage of young salmonids and trout that are between the egg and fry stage. The alevin has not absorbed its yolk sac and has not emerged from the spawning gravels.

Anadromous fish: Fish that hatch in freshwater, migrate to the ocean, mature there and return to freshwater to spawn. For example, salmon or steelhead.

Apron: A smooth (generally concrete) surface that is placed between culvert and channel to improve capacity and reduce erosion.

Attractant flow: A flow of water at a barrier used to attract fish into a device so they can be allowed to bypass the barrier.

Backwater: (1) A rise in stage produced by a temporary obstruction or by the flooding of the stream downstream; (2) Water backed-up or retarded in its course as compared with its normal open channel flow condition. Water level is controlled by some downstream hydraulic control; (3) to place a culvert or use a weir such that there will always be some depth of water within the culvert.

Backwater effect: The rise in surface elevation of flowing water upstream from and as a result of an obstruction to flow or by the flooding of the stream downstream. The effect which a dam or other obstruction has in raising the surface of the water upstream from it.

Backwater flooding: Upstream flooding caused by downstream conditions such as channel restriction or high flow in a downstream confluence stream.

Baffle: (1) Wood, concrete or metal mounted in a series on the floor and/or wall of a culvert or fish ladder to increase boundary roughness and thereby reduce the average water velocity in the structure. (2) A flat board or plate, deflector, guide, or similar device constructed or placed in flowing water for one of the following purposes:

- Increase boundary roughness, reducing the average velocity within a channel;
- Reduce channel cross section to increase the velocity within the channel;
- Create low velocity zones for fish holding;
- Deflect flow or control its direction; or
- Create headloss to uniformly distribute flow.

Bankfull width: The width of a river or stream channel between the highest banks on either side of a stream.

Bar (stream or river bar): An accumulation of alluvium (gravel or sand) caused by a localized decrease in water velocity.

Barrier: A hydraulic (height, depth, velocity), physical (natural or manmade), chemical, or temperature barrier to the movement or migration of fish. It may be partial, temporal, or complete. A partial barrier blocks some species or age groups. A temporal barrier is a block at only certain flow conditions. A complete barrier is a block at all times and hydraulic conditions.

Bathymetry: (1) The measurement of the depth of large bodies of water (oceans, seas, ponds and lakes). (2) The measurement of water depth at various places in a body of water. Also the information derived from such measurements.

Biotic: Referring to a live organism.

Box culvert: Culvert of rectangular cross section, commonly of precast concrete.

Braided stream: A complex tangle of converging and diverging stream channels (Anabranches) separated by sand bars or islands. Characteristic of flood plains where the amount of debris is large in relation to the discharge.

Braiding (of river channels): Successive division and rejoining of river flow with accompanying islands.

Bridge: A structure with a span greater than 20 feet built over a lake, stream or river so that people can get from one side to the other.

Burst swimming mode: Fish swimming mode that can only be sustained for a short period of time, about 7 seconds. Also know as darting speed.

Bypass: A pipe or channel used to conduct a liquid around another pipe or a fixture.

Bypass system: A structure that provides a safe route for fish to move through or around a dam, screen, or other barrier.

CALFED Bay-Delta Program: A collaborative effort among 23 state and federal agencies to improve water supplies in California and the health of the San Francisco Bay-Sacramento/San Joaquin River Delta watershed.

Canal: A channel, usually open, that conveys water by gravity to farms, municipalities, etc.

Canal headworks: The beginning of a canal.

Cascade: A short, steep drop in stream bed elevation often marked by boulders and agitated white water.

Channel control: The condition under which the stage-discharge relation of a gauging station is governed by the slope, size, geometry, and roughness of the channel.

Chinook Salmon: *Oncorhynchus tshawytscha*; the largest species of the Pacific salmon, also commonly called "King." Typical adults weigh about 22 pounds (10 kg) and are 36 inches (91 cm) long, but Chinook from some runs can exceed 100 pounds.

Coliform: A group of related bacteria primarily found in human and animal intestines and wastes, and thus widely used as indicator organisms to show the presence of such wastes in water and the possible presence of pathogenic (disease producing) microorganisms.

Confluence: The meeting of two streams.

Conservation storage: The portion of water stored in a reservoir that can be released for all useful purposes such as municipal water supply, power, irrigation, recreation, fish, wildlife, etc. in contrast with storage capacity used for flood control. Conservation storage is the volume of water stored between the inactive pool elevation and flood control stage.

Contraction: The reduction of a cross sectional area of a stream channel.

Control: A natural constriction of the channel, a long reach of the channel, a stretch of rapids, or an artificial structure downstream from a Gauging Station that determines the Stage-Discharge Relation at the gauge. A control may be complete or partial. A complete control exists where the stage-discharge relation at a gauging station is entirely independent of fluctuations in stage downstream from the control. A partial control exists where downstream fluctuations have some effect upon the stage-discharge relation at a gauging station. A control, either partial or complete, may also be shifting. Most natural controls are shifting to a degree, but a shifting control exists where the stage-discharge relation experiences frequent changes owing to impermanent bed or banks.

Conveyance: A measure of the carrying capacity of a stream or channel.

Crest: The top of a dam, weir, dike, or spillway, excluding any parapet walls, railings, etc., which water must reach before passing over the structure; in international usage it refers to the crown of an overflow section of a dam.

Critical: The flow condition at which point the water velocity equals the wave speed.

Critical depth: In a specified stream channel, the water depth at which the specific energy is the minimum for a given rate of flow. Critical depth usually occurs at the point corresponding to an abrupt steepening of channel slopes, such as rapids.

Critical flow: The flow regime at a given discharge for which the specific energy (i.e., combination of velocity energy and depth) are a minimum (Froude number = 1). At depths greater than the critical flow depth, the flow is considered to be tranquil or subcritical. At depths less than the critical flow depth, flow is considered to be rapid or supercritical.

Cross section: Slice of the channel and adjacent valley made perpendicular to the assumed direction of flow. The ground surface and streambed elevations of this slice are used in hydraulic computations.

Cubic feet per second (cfs): Unit expressing rate of discharge. One cubic foot per second is equal to the discharge through a rectangular cross section, one foot wide and one foot deep, flowing at an average velocity of one foot per second. A flow of 1 cfs produces 1.98 af per day, or 448.8 gallons per minute.

Culvert: An enclosed passageway (such as a pipe) that allows streams, rivers, or runoff to pass under roadways and embankments.

Degrade: To decrease channel elevation by sediment removal (erosion or extraction).

Denil Fish Ladder: A prefabricated aluminum chute with baffles extending from the sides and bottoms that are angled upstream. The roughness caused by the baffles slows the flow enough that fish can negotiate it. Denil fishways accommodate more species of fish than other types of fishways and have been used successfully for passing a wide variety of riverine and anadromous fish. Denil fishways function in a wider range of flow conditions than pool and weir fishways. They resist sedimentation but are vulnerable to obstruction by debris.

Dissolved oxygen (DO): The amount of gaseous oxygen (O_2) actually present in water expressed in terms either of its concentration in the volume of water (milligrams of O_2 per liter) or of its share in saturated water (percentage). This concentration is a function of temperature and pressure; for example, the colder the water, the more oxygen it will hold.

Diversion: (1) Transfer of water from a stream, lake, aquifer or other source of water by a canal, pipe, well or other conduit to another watercourse or to the land; (2) Turning aside or alteration of the natural course of a flow of water, normally considered physically to leave the natural channel.

Drought: Periods of less than average or normal precipitation over a certain period of time sufficiently prolonged to cause a serious hydrological imbalance resulting in biological losses (impact flora and fauna ecosystems) and/or economic losses (affecting man).

Ecotype: A locally adopted population of a species which has a distinctive limit of tolerance to environmental factors.

Embankment: An artificial deposit of material that is raised above the natural surface of the land and used to contain, divert, or store water, support roads or railways, or for other similar purposes.

Embedded culvert: A culvert (pipe) of adequate opening to encompass the stream channel width, and emulating the streambed within the culvert by lining the bottom with representative streambed substrate. The natural substrate materials are supplemented with additional larger material to help retain the substrate within the culvert and assist fish passage. By emulating the streambed and stream channel width, the culvert's streamflow characteristics should reflect the natural streamflow characteristics.

Embeddedness: The degree to which the coarse channel bed materials (boulders, cobble, gravel, sand) are surrounded or covered by fine sediments, usually measured as percent coverage by finer sediments.

Exceedance percentage: The amount of time that the specified flow is exceeded. As an example, a 1% flow was only exceeded 1% of the time in the historical record.

Fall-run fish: Anadromous fish that return to spawn in the fall.

Feet per second (fps): Unit expressing rate of velocity.

Fish flows: Artificially increased flows in the river system called for in the fish and wildlife program to quickly move the young fish down the river during their spring migration period.

Fish ladder: A channel or physical structure engineered to provide water velocities and/or drops in elevation that enable adult fish to migrate up a river past dams or other obstructions. Channels through which fish swim are usually flume type structures incorporating a series of baffles to reduce the velocity of the water. Fish swim upstream, resting in pools and bursting through or jumping over the baffles. Most common types are pool and weir, denil, and vertical slot.

Fish screen: A porous barrier placed across the inlet or outlet of a pond or diversion to prevent the passage of fish.

Fishway: A term used to describe a variety of methods and facilities to pass fish up and downstream past barriers and dams. The system may include special attraction devices, entrances, collection, and transportation channels, the fish ladder itself, exit and operating and maintenance standards.

Fixed drawdown period: The period in late summer and fall when the volume of the next spring runoff is not yet known and reservoir storage operations are guided by a fixed rule curve based on historical streamflow patterns.

Flashboards: Lengths of timber, concrete or steel placed on the crest of a spillway to raise the water level, but that may be quickly removed in the event of a flood.

Flood control storage: The space in reservoirs reserved for the sole purpose of regulating flood inflows to abate flood damage.

Floodplain: The area adjacent to a stream, river, or lake that is usually dry but is covered by water during a flood. Usually the flood plain is a low gradient area well covered by various types of riparian vegetation.

Flow augmentation: Increased flow from release of water from storage dams.

Flow regulation: The artificial manipulation of the flow of a stream.

Flume: open artificial channel or chute carrying a stream of water, or acting as a measuring device.

Ford: A stream crossing where the road may be under water.

Froude number: Dimensionless number expressing the ratio of inertial force to gravity force in a fluid.

Fry: A stage of development in young salmon or trout. During this stage the fry is usually less than one year old, has absorbed its yolk sac, is rearing in the stream, and is between the alevin and parr stage of development.

Geomorphology: That branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of land forms. In river (fluvial) systems, it includes factors such as; stream gradient, elevation, parent material, stream size, valley bottom width, and others.

Glide: Portion of the water column in which the flow is characterized by slow moving laminar flow, similar to that which would be found in a shallow canal. Water surface is smooth and the gradient over a glide is nearly zero. Velocity is slow, but flow is shore to shore without eddy development. A glide is too shallow (water depth generally less than two feet) to be a pool but the water velocity is too slow (generally less than one cubic foot per second) to be a run.

GPS unit: Global Positioning System unit – a receiver that allows you to interact with the GPS satellite system for navigation and other applications.

Groundwater: (1) Water within the earth that supplies wells and springs; (2) Water in the zone of saturation where all openings in rocks and soil are filled, the upper surface of which forms the water table.

Headgate: A structure that controls water flow into irrigation canals and ditches. A watermaster regulates the headgates during water distribution and posts headgate notices declaring official regulations.

Headwall: A vertical wall built around the top and sides of a culvert end to secure adjacent soil.

Headwater: The source and upper reaches of a stream, river, or reservoir.

Headworks: A flow control structure at the beginning of an irrigation canal.

HEC-RAS: Hydraulic modeling software developed by the U.S. Army Corps of Engineers Hydraulic Engineering Center (HEC). The software allows rapid one-dimensional steady and unsteady flow calculations.

Hydraulic jump: The sudden and usually turbulent passage of water in an open channel from low stage, below critical depth, to high stage, above critical depth. During this abrupt transition, the velocity changes from supercritical to subcritical. There is considerable loss of energy during the jump. Also known as a standing wave.

Hydraulics: (1) The study of water flow through/over structures such as dams or through natural channels; (2) The study of liquids, particularly water, under all conditions of rest and motion.

Hydrograph: A graph showing stage, flow, velocity, or other property of water with respect to time.

Hydrology: (1) the size and frequency of flows in a river; (2) The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff; (3) The scientific study of the water of the earth, its occurrence, circulation and distribution, its chemical and physical properties, and its interaction with its environment, including its relationship to living things;

Impoundment: (1) to collect and confine water as in a pond or reservoir. (2) A body of water confined by a dam, dike, floodgate or other barrier.

Inflow: Water that flows into a body of water.

Inlet structure: An arrangement of apron and wing walls that smoothes the hydraulic transition from open channel to culvert flow and increases maximum capacity. It may also be the mounting point for a trash rack.

Invert: The bottom of a culvert.

Jump height: Vertical distance between water surfaces of two pools

Jump pool: The "take-off" pool at the base of a fall. Generally must be a minimum of 1.25 times as deep as the jump height for leaping salmonids. A pool located just downstream of the low crest of a fixed-crest barrier that provides sufficient depth for a fish to accelerate to a speed necessary to jump high enough to clear the barrier crest.

Juvenile: Fish from one year of age until sexual maturity.

Juvenile salmon: All early lifestages of downstream migrating salmon (fry through smolt).

Left bank: Left side bank of a channel when looking in the direction of flow.

Levee: An embankment constructed to prevent a river from flooding. A natural or man-made barrier that helps keep rivers from overflowing their banks.

Low-flow road crossing: A road crossing a streambed that is intended to be submerged at higher flows.

Mainstem: The major reach of a river or stream formed by the smaller tributaries which flow into it.

Meander: The tendency of a channel to move laterally; the bends in a stream or river.

Outfall: Place where a stream discharges; outlet or structure through which reclaimed water or treated effluent is discharged.

Outlet: Point where water exits from a stream, river, lake or artificial drain.

Outlet structure: An arrangement of apron, wing walls and sometimes energy absorption structure at the end of a culvert.

Outmigration: The movement of juvenile salmon or steelhead fish from their natal streams down the river system to the ocean.

Parr: The developmental life stage of juvenile salmon and trout between alevin and smolt, when the young have developed large dark spots on their sides (parr marks) with for camouflage and are actively feeding in fresh water. Salmon parr usually live in freshwater for 1 to 2 years.

Parr marks: Dark vertical bars on the sides of young salmon.

Passage: The movement of migratory fish through, around, or over dams, reservoirs and other obstructions in a stream or river.

Plunge pool: A natural or artificially created pool that dissipates the energy of free-falling water.

Pool: A portion of a stream where water velocity is slow and the depth is greater than the riffle, run or glide. Pools often contain large eddies with widely varying directions of flow compared to riffles and runs where flow is nearly exclusively downstream. The water surface gradient of pools is very close to zero and their channel profile is usually concave.

Prolonged swimming mode: Fish swimming mode that can be endured for some time, 7 seconds to minutes, but results in fatigue.

Raw water: Water in its natural state, prior to any treatment for drinking.

Reach: A section of channel.

Rear: To feed and grow in a natural or artificial environment.

Rearing: Refers to the juvenile life stage of anadromous fish spent feeding in nursery areas of freshwater rivers, lakes and streams before they migrate to the ocean.

Rearing habitat: Areas in rivers or streams where juvenile salmon and trout find food and shelter to live and grow.

Redd: Pit-like nest dug in the gravel of a stream bottom by a female fish where eggs are laid, fertilized by the male and re-covered with gravel. Redds are usually located in areas associated with flowing water and clean gravel. Fishes that utilize this type of spawning area include trout, salmon, some minnows, etc.

Riffle: A shallow portion of the stream extending across a stream bed characterized by relatively fast moving turbulent water. The water column in a riffle is usually constricted and water velocity is fast due to a change in surface gradient. The channel profile in a riffle is usually straight to convex.

Right bank: Right side bank of a channel when looking in the direction of flow.

Riparian: of or pertaining to the banks of a body of water.

Riparian area: An area of land and vegetation adjacent to a stream that has a direct effect on the stream. This includes woodlands, vegetation, and floodplains.

Riparian habitat: The aquatic and terrestrial habitat adjacent to streams, lakes, estuaries, or other waterways.

Riparian vegetation: The plants that grow rooted in the water table of a nearby wetland area such as a river, stream, reservoir, pond, spring, marsh, bog, meadow, etc.

Riparian water right: The legal right held by an owner of land contiguous to or bordering on a natural stream or lake, to take water from the source for use on the contiguous land.

Riparian zone: A stream or other body of water and all the vegetated area on its banks.

Riprap: Rocks or concrete pieces used to stabilize embankments, streams or river banks from erosion.

Riverine: Relating to, formed by, or resembling a river including tributaries, streams, brooks, etc.

River miles: Miles from the mouth of a river to a specific destination or, for upstream tributaries, from the confluence with the main river to a specific destination.

Rock slope protection: The use of graded rock placed to protect a slope against wave action or erosion.

Run: A relatively shallow portion of a stream characterized by relatively fast moving non-turbulent flow. A run is usually too deep to be considered a riffle and too shallow to be considered a pool. The channel profile under a run is usually a uniform flat plane.

Run (of fish): A group of fish of the same species that migrate together up a stream to spawn, usually associated with the seasons, e.g., fall, spring, summer, and winter runs. Members of a run interbreed, and may be genetically distinguishable from other individuals of the same species.

Runoff: The part of precipitation or irrigation water which is not absorbed into the ground, but flows across land and eventually runs off into streams and other surface water.

Salmonid: A fish of the Salmonidae family, which includes soft-finned fish such as salmon, trout and whitefish.

Scour: Erosion at the exit of an open channel, culvert, or spillway.

Sediment: Soil, sand and other solid materials washed from land into waterways.

Sedimentation: When soil particles (sediment) settle to the bottom of a waterway.

Septic system: A system for treating wastewater from an individual home or business, or a group of homes or businesses that relies on natural anaerobic and aerobic bacterial decomposition processes to treat wastewater and return it to the environment. A conventional onsite septic system consists of a gravity-fed septic tank designed to separate solid matter from liquid effluent, and a gravity-fed leachfield whose soils absorb and further treat effluent. Properly designed and maintained, a septic system can effectively and naturally treat wastewater for 20-30 years.

Sheet flow: Flow over plane, sloped surfaces in a thin layer; dispersed flow of water.

Silt: Substrate particles smaller than sand and larger than clay.

Slide gate: A gate that can be opened or closed by sliding it in supporting guides.

Smolt: Salmonid or trout developmental life stage between parr and adult, when the juvenile is at least one year old, migrating downstream from freshwater to saltwater and has adapted to the marine environment. When parr become smolts, they lose their spots and turn silvery.

Span: (1) The extent or measure of space between abutments or supports, as of a bridge or roof; breadth. (2) To extend across.

Spawn: The reproductive process for aquatic organisms which involves a female fish producing or depositing eggs and a male fish discharging sperm.

Spawning gravel: Sorted, clean gravel patches of a size appropriate for the needs of resident or anadromous fish.

Steelhead: *Oncorhynchus mykiss*; an anadromous form of rainbow trout that spawns in fresh water and spends a portion of its lifecycle in the ocean.

Storage: (see also conservation storage) (1) Water artificially impounded in surface or underground reservoirs for future use. (2) Water naturally detained in a drainage basin, such as ground water, channel storage, and depression storage.

Storage capacity, surcharge: The volume of a reservoir between the maximum water surface elevation for which the dam is designed and the crest of an uncontrolled spillway, or the normal full-pool elevation with the crest gates in the normal closed position.

Storage capacity, total: The total volume of a reservoir exclusive of surcharge.

Streamflow: The discharge that occurs in a natural channel. Although the term discharge can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. Streamflow is a more general term than runoff, as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Subcritical flow: Relatively tranquil flow that occurs at depths greater than the critical flow depth (Froude number less than one). In this state, the role played by gravity forces is more pronounced, so the flow has low velocity and is often described as tranquil and streaming.

Supercritical flow: Relatively rapid flow that occurs at depths smaller than the critical flow depth (Froude number greater than one). In this state, the inertia forces become dominant, so the flow has a high velocity and is usually described as rapid, shooting, and torrential.

Sustained swimming mode: The swimming mode of a fish that can be maintained indefinitely without fatigue.

Tail out: The downstream end of a pool where the bed surface gradually rises. It may vary in length, but usually occurs immediately upstream of a riffle.

Tail water: Water immediately downstream from a structure.

Thalweg: The line following the lowest part of a valley, whether under water or not. Usually the line following the deepest part of the bed or channel of a river.

Trashrack: A metal grate placed at the upstream end of a culvert to prevent woody debris, rocks, etc. from entering the culvert.

Tributary: A smaller stream that contributes its flow to another, typically larger, stream or body of water.

Turbidity: A measure of the amount of finely divided suspended matter in water, which causes the scattering and adsorption of light rays and causes a cloudy appearance. Turbidity is usually reported in arbitrary nephalometric turbidity units (NTU) determined by measurements of light scattering. Excess turbidity will reduce light penetration, which leads to fewer photosynthetic organisms available to serve as food sources for many invertebrates. As a result, overall invertebrate numbers may also decline, which may then lead to a fish population decline. Fish may suffer clogging and abrasive damage to gills and other respiratory surfaces. Abrasion of gill tissues triggers excess mucous secretion, decreased resistance to disease, and a reduction or complete cessation of feeding.

Turbulence: A type of flow characterized by the chaotic movements of swirls, cross currents and eddies. Turbulence may be caused by surface roughness or protrusions, changes in channel size, or excessive flow rates. Turbulence can also be created when streams of fluid of different speeds and direction come into contact with each other.

Unimpaired passage: Adequate conditions for passage exist for the considered salmonid and/or life stage.

Velocity barrier: (1) Flow across a structure or through a culvert that is exceeds the swimming ability of a fish, preventing further migration. (2) A physical structure, such as a barrier dam or floating weir, built in the tailrace of a hydroelectric powerhouse, which blocks the tailrace from further adult salmon or steelhead migration to prevent physical injury or migration delay.

Watershed: The area of land from which precipitation drains to a single point. Watersheds are sometimes referred to as drainage basins or drainage areas.

Weir: A low dam-like structure that spans a channel for the purpose of controlling the local streambed elevation (grade control weir), raising the upstream water level (fixed-crest weir when uncontrolled), or measuring flow (measuring or gauging weir).

Wing wall: A flaring vertical wall on either side of a culvert or bridge abutment.

Chapter 8 References

Baker, Peter F. and J. Emil Morhardt. 2001. Survival of Chinook salmon smolts in the Sacramento – San Joaquin Delta and Pacific Ocean. In: Brown, Randall L. (ed.), Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179. California Department of Fish and Game. Sacramento. Vol. 2, 163 – 182.

Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991. Fundamentals of Culvert Design for Passage of Weak-Swimming Fish, Final Report. Alaska DOT&PF and USDOT, Federal Highway Administration, FHWA-AK-RD-90-10.

Bell M.C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. 3rd Edition. Fish Passage Development and Evaluation Program, US Army Corps of Engineers, North Pacific Division, Portland, OR.

Calaveras County Water District. 2002. Calaveras River Watershed Management Plan. Phase I. San Andreas, CA.

CALFED Bay-Delta Program. 1999. Monitoring, Assessment, and Research on Central Valley *O. mykiss*: Status of Knowledge, Review of Existing Programs, and Assessment of Needs, Interagency Ecological Program *O. mykiss* Project Workteam. Developed for the CALFED Comprehensive Monitoring Assessment and Research Program, Technical Appendix VII – A – 11. March.

CALFED Bay-Delta Program. 1999. Ecosystem Restoration Program. CALFED Bay-Delta Program. Sacramento.

CALFED Bay-Delta Program. 2000. Final Programmatic EIS/EIR. Ecosystem Restoration Program. Volume II. Sacramento. July.

[DFG] California Department of Fish and Game. 1993. Restoring Central Valley Stream: A Plan for Action. Inland Fisheries Division. Compiled by F.L. Reynolds, T.J. Mills, R. Benthin, and A. Low. Report for public distribution, Nov 10, 1993. Inland Fisheries Division, Sacramento.

[DFG] California Department of Fish and Game. 2002. Culvert Criteria for Fish Passage. The Resources Agency, Sacramento. 15p.

[DFG] California Department of Fish and Game. 2003. California Salmonid Stream Habitat Restoration Manual. Chapter IX. Sacramento. Apr.

CH2MHill. 2005. Calaveras River Anadromous Fish Protection Project. Prepared for Stockton East Water District and Calaveras County Water District. Redding, CA. Apr.

Demko D.B., C. Gemperle, A. Phillips, and S.P. Cramer. 2000. Outmigrant Trapping of Juvenile Salmonids in the Lower Stanislaus River Caswell State Park Site 1999. Prepared for the USFWS by S.P. Cramer & Associates, Inc. Gresham, OR.

Fishery Foundation of California. 2000. Calaveras River Chinook Salmon and Steelhead Population Abundance and Limiting Factors Analysis – CALFED ERP Grant Proposal. P.O. Box 27114 Concord, CA 94527.

Fishery Foundation of California. 2004. Bellota Weir Maintenance Recommendations.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual. Inland Fisheries Division, California Department of Fish and Game, Sacramento.

Groot, C. and L. Margolis, Eds. 1991. Reprinted 1998. Pacific Salmon Life Histories. Department of Fisheries and Oceans. Biological Sciences Branch. Pacific Biological Station. Nanaimo, British Columbia, Canada.

Hallock, Richard J., Robert F. Elwell, and Donal H. Fry Jr. 1970. Migrations of Adult King Salmon *Oncorhynchus tshawytscha* in San Joaquin Delta as Demonstrated by the Use of Sonic Tags. Fish Bulletin 151. California Department of Fish and Game.

Hunter, Lary A. and Lesley Mayor. 1986. Analysis of Fish Swimming Performance Data: Volume I. South/North Consultants Inc., Winnipeg, Manitoba. 33 pages.

Moyle, Peter B. 2002. Inland Fishes of California. University of California Press. Berkeley, CA.

[NMFS] NOAA's National Marine Fisheries Service. 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. Feb.

[NMFS] NOAA's National Marine Fisheries Service. 2000. Guidelines for Salmonid Passage at Stream Crossings. Draft. Southwest Region. May.

[NMFS] NOAA's National Marine Fisheries Service. 2001. Guidelines for Salmonid Passage at Stream Crossings. Final draft. Southwest Region. Sep.

[NMFS] NOAA’s National Marine Fisheries Service, Office of Protected Resources. 2003. Endangered, Threatened, and Candidate Species, www.nmfs.noaa.gov/prot_res/species/fish/Chinook_salmon.html. May.

Oregon Department of Fish and Wildlife. 1997. Oregon Department of Fish and Wildlife Guidelines and Criteria for Stream-Road Crossings. 7 p.

Robison, E.G., A. Mirati, and M. Allen. 2000. Oregon Road/Stream Crossing Restoration Guide: Spring 1999. Advanced Fish Passage Training Version. 75 p.

S.P. Cramer & Associates. 2004. Bellota Fish Ladder Operating Criteria (Non-Irrigation Season). June.

Stillwater Sciences. 2000. Calaveras River Spawning Gravel Assessment. Technical Memorandum for USFWS Anadromous Fish Restoration Program.

Stillwater Sciences. 2004. Lower Calaveras River Chinook Salmon and Steelhead Trout Limiting Factors Analysis. First Year Report (Revised). Prepared for Fishery Foundation of California. Elk Grove, CA. Available at: www.delta.dfg.ca.gov/afrp/documents/Final_Report_mrs091004_jrr091704.pdf

[SEWD] Stockton East Water District. 2001. Fall/Winter Calaveras River and Mormon Slough Operational Plan. Stockton, CA. December.

Tetra Tech EM Inc. 2000. Final Field Assessment Report Calaveras River Watershed Management Program. 10670 White Rock Road, Suite 100 Rancho Cordova, CA 95249.

[USACE] US Army Corps of Engineers. 1983. New Hogan Dam and Lake: Calaveras River, California. Water Control Manual. Appendix III to Master Water Control Manual San Joaquin River basin, California. Sacramento District.

[USACE] US Army Corps of Engineers. 1989. Draft Environmental Assessment Calaveras River Reconnaissance Study for Flood Control. Sacramento District, Corps of Engineers.

US Department of Commerce. 1998. NOAA's National Marine Fisheries Service. 50 CFR Part 227. Endangered and Threatened Species; Threatened Status for Two ESU's of *O. mykiss* in Washington, Oregon, and California.

[USDOT] US Department of Transportation, Federal Highway Administration. 1990. Fish Passage through Culverts. Report No. FHWA-FL-90-006. Washington D.C.

[USFWS] US Fish and Wildlife Service. 1989a. Memorandum on Groundwater Recharge Demonstration Program – Stockton East Project on the Calaveras River. Prepared for US Bureau of Reclamation. August.

[USFWS] US Fish and Wildlife Service. 1989b. Planning Aid Letter: Calaveras River and Mormon Slough Flood Control Investigation. Sacramento, CA. October.

[USFWS] US Fish and Wildlife Service. 1993. Memorandum from Wayne S. White, Field Supervisor, Sacramento Field Office, Sacramento, California to David Lewis, Regional Director, US Bureau of Reclamation, Sacramento, CA. 28 Jan.

[USFWS] US Fish and Wildlife Service. 1998. Central Valley Project Improvement Act Tributary Production Enhancement Report. Central Valley Fish and Wildlife Restoration Program Office. Sacramento, CA. May.

Vyverberg, Kris, Bill Snider, and Robert G. Titus. 1997. Lower American River Chinook Salmon Spawning Habitat Evaluation: An Evaluation of Attributes Used to Define the Quality of Spawning Habitat. California Department of Fish and Game. Environmental Services Division.

Williams, John G., Kris Vyverberg, Tim Homer, and Joe Merz. 2003. The Hyporheic Environment of Larval Chinook Salmon (*Oncorhynchus tshawystcha*) in Central Valley Streams.

Yoshiyama, M. Ronald, Eric R. Gerstung, Frank W. Fisher, and Peter Moyle. 1995. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In: Sierra Nevada Ecosystem Project: Final Report to Congress, Vol. III – Assessments, Commissioned reports, and Background Information. Pp 309 – 362. Centers for Water and Wildland Resources, University of California, Davis. Davis, CA.

Yoshiyama, Ronald, Eric R. Gerstung, Frank W. Fisher, and Peter B. Moyle. 2000. Chinook Salmon in the California Central Valley: An Assessment. In: Fisheries, Volume 25:Issue 2. Pp 6-22. Feb.

Personal Communication

Collins, Dillon, S.P. Cramer and Associates. Dec 2002. Dillon.Collins@valleyair.org

Heise, George, DFG. 2 Sep 2004. GHEISE@dfg.ca.gov.

Heise, George, DFG. 20 Feb 2007. DHEISE@dfg.ca.gov

Heise, George, DFG. 11 Apr 2007. DHEISE@dfg.ca.gov

Hendrick, Michael, DWR. 2005. hendrick@water.ca.gov

Holcomb, Phil, USACE. 2 Aug 2005. phillip.holcomb@usace.army.mil

Inman, Jim, SP Cramer and Associates. Aug 2005. inman@spcramer.com

Kennedy, T. 25 Dec 2002. Via e-mail to Glenda Marsh, DWR.

Wickert, J.D., USFWS. Aug 2005. John_Wickert@fws.gov